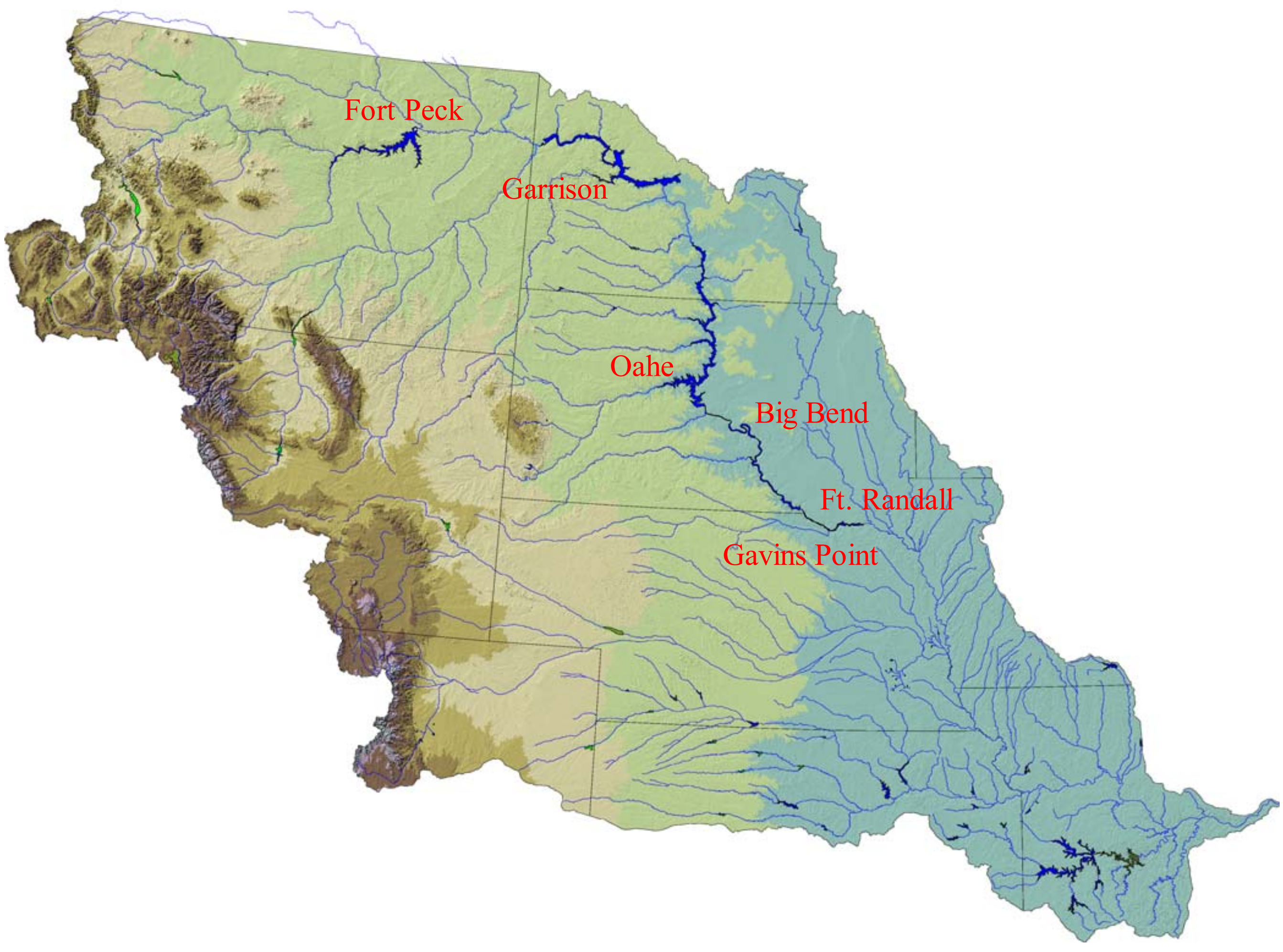
US Army Corps
of Engineers

Northwestern Division

Missouri River Mainstem Reservoir System

Master Water Control Manual

Missouri River Basin



Reservoir Control Center
U. S Army Corps of Engineers
Northwestern Division - Missouri River Basin
Omaha, Nebraska

March 2004

DEPARTMENT OF THE ARMY
NORTHWESTERN DIVISION, CORPS OF ENGINEERS
12565 WEST CENTER ROAD
OMAHA, NEBRASKA 68144-3869

REPLY TO
ATTENTION OF:

March 19, 2004

The Missouri River Master Water Control Manual Review and Update Study, which resulted in the selection of the water control plan described in this Master Manual, was initiated in 1989 to investigate whether changes could be made to better meet the contemporary needs of the basin. This Master Manual and the selected water control plan, which have been approved by me in the attached Record of Decision, mark the completion of 14 years of study and debate on the long-term management of the Missouri River Mainstem Reservoir System (Mainstem System). I believe the selected water control plan presented in this Master Manual provides the best balance in meeting the contemporary needs of the basin, serves the Congressionally authorized purposes of the Mainstem System, meets the Corps' treaty and trust obligations to Federally recognized tribes, and complies with other Federal laws including the National Environmental Policy Act and Endangered Species Act.

This Master Manual and the selected water control plan are also intended to be non-binding guidelines to be used by the Corps in regulating and operating the Mainstem System. In South Dakota v. Ubbelohde, 330 F. 3d. 1014, the Eighth Circuit Court of Appeals held that the Corps' prior manual was a binding regulation. This was not the Corps' intent and, accordingly, the Master Manual has been amended to clearly reflect the Corps' intent that it not be considered a binding regulation. This is consistent with Corps' regulations that allow for both updates for changes in normal regulations as well as for deviations to the approved water control plans.

The Corps and the U.S. Fish and Wildlife Service have been working to define the needs of the Missouri River threatened and endangered species protected under the Endangered Species Act. This Master Manual continues and expands upon that relationship. The selected water control plan and the comprehensive threatened and endangered species recovery program, embrace the concept that water management and physical changes should be based on sound scientific and engineering principles and practices, the results of comprehensive monitoring and evaluation, and input from basin stakeholders.

Public participation in the soon-to-be-established Missouri River Recovery Implementation Committee will be critical to efforts to recover these protected species. The Corps is dedicated to this effort and is committed to serve the Nation and its citizens in protecting one of our National treasures - the Missouri River. We are also committed in working with all basin interests, including the Tribes and States, as well as public and private interest groups, to assure that the implementation of the selected plan as the current water control plan (CWCP), as presented in this Master Manual, as well as any future changes, are coordinated within the basin.

The Corps looks forward to our participation in this regional partnership in carrying out our stewardship responsibilities to the Nation and the region in the implementation of the CWCP and the regulation of the Missouri River Mainstem System.

[redacted]

Enclosures

William T. Grisoli
Brigadier General, U.S. Army
Division Engineer

DEPARTMENT OF THE ARMY
NORTHWESTERN DIVISION, CORPS OF ENGINEERS
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REPLY TO
ATTENTION OF:

RECORD OF DECISION
MISSOURI RIVER MASTER WATER CONTROL MANUAL
REVIEW AND UPDATE

I have reviewed the Missouri River Master Water Control Manual Review and Update Final Environmental Impact Statement (FEIS), March 2004; the U.S. Fish and Wildlife Service's (USFWS) 2000 Biological Opinion[1] and 2003 Amendment[2] to the 2000 Biological Opinion (2003 Amended BiOp) on the operation of the Missouri River Mainstem Reservoir System, the operation and maintenance of the Missouri River Bank Stabilization and Navigation Project, and the operation of the Kansas River Reservoir System; as well as comments and correspondence received in response to the public coordination of these documents. I find the preferred alternative water control plan as described in the FEIS and as modified in this Record of Decision (herein Selected Plan) is consistent with all statutory and regulatory requirements, including applicable environmental statutes and the Corps' treaty and trust responsibilities to the Missouri River Basin Tribes; provides for the Congressionally authorized uses of the Mainstem Reservoir System (System); and is in the public interest. I therefore approve the Selected Plan for the System, and its incorporation into the new Missouri River Master Water Control Manual (Master Manual) for the System.

The System is comprised of six dam and reservoir projects authorized by the Rivers and Harbors Act of 1935 and the Flood Control Act of 1944 to operate as an integrated system providing for flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife. In enacting the 1944 Flood Control Act, Congress did not assign a priority to these operational purposes. Instead, it was contemplated that the Corps, in consultation with affected interests and other agencies, would consider all of the authorized purposes when making decisions to optimize development and utilization of the water resources of the Missouri River basin to best serve the needs of the people. The FEIS did not assume a priority for any economic use or environmental resource, and recognized there may be occasions where conflicts exist between the individual authorized purposes. The new Master Manual describes the water control plan and the objectives for the integrated regulation of the System by providing guidance for the regulation of Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point projects.

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[1] Transmitted by letter dated November 30, 2000.
[2] Transmitted by letter dated December 16, 2003.

The Selected Plan includes several changes from the previous Master Manual's water control plan. The modifications are as follows:

- drought conservation measures;
- unbalancing of the upper three reservoirs;
- non-navigation flows; and
- an adaptive management process.

Drought Conservation Measures

Under the Selected Plan, the navigation service level and season length would be reduced to conserve stored water in the upper reservoirs during extended drought periods. The drought conservation criteria consist of "guide curves" for the determination of flow support for navigation and other downstream purposes and navigation season length.

The Selected Plan calls for suspension of navigation service if System stored water is at or below 31 MAF on March 15 of any year, which would most likely coincide with a national drought emergency. If any of the studies performed for the development of the Annual Operating Plan (AOP) indicate that the amount of stored water will be at or below 31 MAF by the upcoming March 15, the Corps will notify the Secretary of the Army. Also, approval from the Secretary of the Army will be required prior to implementation of back-to-back non-navigation years. The Corps will promptly inform basin stakeholders of a notification to the Secretary of the Army and of the Secretary's decision regarding suspension of navigation.

Unbalancing of the Upper Three Reservoirs

Intra-system unbalancing under the Selected Plan is implemented in those years when the reservoirs are not drawn down as a result of severe droughts. The unbalancing process is rotated among the upper three reservoirs on a 3-year cycle. Intra-system unbalancing provides for resident fishery production by lowering one of the three reservoirs allowing vegetation to grow around the rim. The subsequent year the reservoir is refilled, inundating the vegetation around the perimeter, which is used by adult fish for spawning and by young reservoir fish to hide from predators. The third year, the reservoir rises during the fish spawn and then slowly falls for the remainder of the year so that it is positioned to be at low elevation the following year. Unbalancing would also provide more emergent sandbar and shoreline habitat for the Endangered Species Act (ESA) listed birds.

Non-navigation Flows

The Selected Plan includes minimum flows for periods when navigation is not supported during droughts, or other "non-navigation" periods. These flows provide for water supply to the thermal powerplants and other municipal and industrial intakes on the river or reservoirs. Concerns were expressed regarding adequate flows to provide for cooling at thermal powerplants in the summer, and to serve water supply intakes during river ice conditions in the winter. This resulted in the inclusion of higher non-navigation flows in the Selected Plan. The Selected Plan recognizes that all of the System dams will be regulated to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the System reservoirs, to the extent reasonably practicable.

Adaptive Management Process

The Selected Plan includes an adaptive management process that recognizes scientific uncertainty and the potential for future physical changes. As physical changes occur or uncertainties are reduced, the adaptive management element of the Selected Plan allows flexibility to adjust System regulation. System regulation changes have been made using an adaptive management approach for many years.

The Corps recognizes that changes in the operation of the System may impact many river uses and is committed to ensuring that the public is actively involved and well informed of potential changes in System regulation and has the opportunity to comment on those proposed changes prior to any decision on implementation. The adaptive management process will be used to implement changes designed to improve the benefits provided by the System, including benefits to the threatened and endangered species. Decisions regarding actions proposed through the adaptive management process will meet the Corps' treaty and trust responsibilities to the Tribes and conform to all of the applicable requirements of Federal laws including the National Environmental Policy Act, Endangered Species Act, and the Flood Control Act of 1944.

The Corps' public AOP process will continue under the Selected Plan. The AOP process involves the development and publishing of a draft in the fall of each year. The Draft AOP forecasts the regulation of the System for various runoff scenarios for the remainder of the current year, plus the following calendar year. After public meetings and comments are received, appropriate changes are made to produce a Final AOP. In the spring, the Corps again conducts public information meetings providing the current hydrologic conditions in the basin and the expected effects of System regulation for the remainder of the year given the forecast and likely runoff scenarios. The System is regulated to follow the Final AOP as closely as possible for the remainder of the year. Not all operating circumstances are covered in the AOP; flexibility to deviate from the Final AOP is necessary and prudent for unusual or changed circumstances. This flexibility allows the Corps to regulate the System for unanticipated events. Significant deviations will be coordinated and approved by the Northwestern Division Commander.

Responsibilities Under the Endangered Species Act

The Selected Plan, in combination with a comprehensive Missouri River Recovery Implementation Program (MRRIP), fulfills the Corps responsibilities under the ESA. The U.S. Fish and Wildlife Service (USFWS), in the 2003 Amendment to the 2000 Biological Opinion (Amended 2003 BiOp), made a no jeopardy determination for the endangered interior least tern and the threatened piping plover, and a jeopardy determination with a Reasonable and Prudent Alternative (RPA) for the endangered pallid sturgeon. The USFWS also concluded the Selected Plan will not destroy or adversely modify piping plover critical habitat.

The RPA flow components for pallid sturgeon replaced the Corps' proposed three-year re-evaluation with a "feasibility, flow development, and adaptive management" element to determine how flows can be provided that are essential for the survival of the pallid sturgeon by March 2006. The evaluation of a "spring rise" described in the 2003 Amended BiOp will include a review of the status of the species, the scientific findings of a research, monitoring, and evaluation program, the progress and success of measures implemented to date, and other relevant new information. Decisions concerning implementation of additional measures or modification of existing measures, including potential release changes out of Gavins Point Dam, will be made through the adaptive management process. The two-year re-evaluation will include input from Missouri River stakeholders to foster conservation of ESA-listed species and the broader ecosystem values of the Missouri River while providing other Congressionally authorized System project purposes. This process has been incorporated into the Selected Plan.

Another RPA element states that when 1,200 acres of new shallow water habitat for pallid sturgeon have been made available, the Corps, in consultation with the USFWS, may modify the summer flows to take advantage of that habitat and more fully meet the Congressionally authorized System project purposes. In letters to the USFWS dated February 13, 2004 and March 2, 2004, the Corps identified a plan and biological rationale to support development of shallow water habitat in an expanded reach from Ponca State Park to the Osage River by July 1, 2004. By letter dated March 5, 2004, the USFWS concurred that there is sufficient biological information to support the expanded reach and also supported the Corps' decision to develop 1,200 new acres of shallow water habitat as a means to address an immediate need for survival and recovery of the pallid sturgeon. The Corps and USFWS will consult in early June 2004 to take into account the newly developed shallow water habitat in association with a request for flow modification to provide for all project purposes including service to navigation throughout the summer of 2004. The Selected Plan reflects this agreed upon approach to implement this element of the RPA.

As set forth above, the FEIS and this Record of Decision, which have been prepared pursuant to the National Environmental Policy Act, address, among other things, the Corps' responsibilities concerning compliance with the requirements of the ESA for the flow measures related to the operation of the Missouri River Mainstem System. The Corps will address in separate correspondence to the USFWS its commitment to the non-flow measures contained in the 2003 Amended BiOp. That correspondence will also contain the details of the status and progress of the Corps' implementation of all the non-flow measures, including habitat development, pallid sturgeon research and monitoring.

Other Considerations

Careful consideration was given to the overall public interest and the economic, social, cultural and environmental effects throughout the development of the Selected Plan, which is the environmentally preferred plan. All applicable laws, Executive Orders, regulations and local plans were considered in evaluating the alternatives. Over 500 alternatives were addressed in four draft EISs and the FEIS. The analysis of these alternatives, and the comments and discussions they engendered are incorporated here by reference. All practicable means were adopted to avoid or minimize adverse impacts, and existing actions and programs are in place to address adverse impacts to the warm water fishery below Fort Peck and Fort Randall and historical properties including Tribal cultural resources and historical sites. System stored water and releases are monitored to ensure that the System regulation enhances water quality consistent with applicable provisions of the Clean Water Act, to the extent reasonably possible.

The Corps will conduct the appropriate surveys, provide required documentation, and enter into appropriate Memoranda of Agreement or Programmatic Agreements to address any adverse effects to cultural resources that may result from implementation of the Selected Plan. Cultural resources management plans are being developed for all lands owned and managed by the Corps. In addition, special emphasis has been given to the development of a Section 106 Programmatic Agreement for the operation and management of the System. This agreement has been drafted in consultation with Tribes, the Advisory Council on Historic Preservation, certain State Historic Preservation Officers, the National Trust for Historic Preservation, and other interested parties. The completion of the management plans and the programmatic agreement will address the Corps' compliance with the National Historic Preservation Act.

In addition, actions are being taken by the Corps under the MRRIP to restore the Missouri River ecosystem, and to protect and recover ESA-listed species. These actions include habitat restoration, hatchery support, and a comprehensive research, monitoring and evaluation program for the three ESA-listed species. MRRIP actions will be identified, reviewed, modified, and implemented through coordination with a Missouri River Recovery Implementation Committee, which will include stakeholder representation to ensure a comprehensive approach to recovery implementation while providing for other Congressionally authorized System project purposes.

In an order dated February 26, 2004, the United States District Court for the District of Minnesota, in Case No. 03-MD-1555 (PAM), In re: Operation of the Missouri River System Litigation, ordered the Corps to sign the Record of Decision by March 19, 2004.

The notice of availability of the FEIS filed in the Federal Register (FR) by the Environmental Protection Agency (EPA) also contained a waiver of the 30-day review period for the FEIS, see 69 FR 10442-10443 (2004).

Statement of Decision

Based on the foregoing, I hereby adopt the Selected Plan for incorporation into Chapter 7 of the new Master Manual. In addition, the new Master Manual is hereby approved for use as the Missouri River Mainstem Reservoir System Master Water Control Manual effective March 19, 2004. Periodic review of the water control plan will provide opportunities to make adjustments. Appropriate public coordination to satisfy environmental, economic and technical issues will occur prior to any modifications. The public will best be served by implementation of the Selected Plan set forth in this Record of Decision.

[redacted]

Date: 19 MAR '04

William T. Grisoli
Brigadier General, U.S. Army
Division Engineer

MISSOURI RIVER BASIN
MAINSTEM RESERVOIR SYSTEM
MASTER WATER CONTROL MANUAL

In 7 Volumes — Volume 1

MASTER MANUAL

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APPENDICES

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<u>PLATES</u>

ABBREVIATIONS

AOP	-	annual operating plan
ARPA	-	Archaeological Resources Protection Act
ac.ft.	-	acre-feet
AF	-	acre-feet
B	-	Billion
BIA	-	Bureau of Indian Affairs
BiOp	-	November 2000 U.S. Fish and Wildlife Service Biological Opinion
BSNP	-	Missouri River Bank Stabilization and Navigation Project
cfs	-	cubic feet per second
COOP	-	Continuity of Operations Plan
CO-OP)	-	cooperative stream-gaging program
Corps	-	Corps of Engineers
COE	-	Corps of Engineers
con't	-	continued
CRREL	-	Corps' Cold Regions Research and Engineering Laboratory
CSU/DSU	-	Channel Service Unit/Data Service Unit
CY	-	calendar year (January 1 to December 31)
CWCP	-	current water control plan
CWMS	-	Corps' Water Management System
DCP	-	Data Collection Platform
DOMSAT	-	DOMestic SATellite
DRGS	-	Direct Readout Ground Station
DRM	-	Daily Routing Model
DSS	-	HEC-Data Storage System
EIS	-	Environmental Impact Statement
elev	-	elevation
EPA	-	Environmental Protection Agency
EMWIN	-	Emergency Managers Weather Information Network
ERDC	-	Corps' Engineering Research and Development Center
EOC	-	Emergency Operations Center
ESA	-	Endangered Species Act
F	-	Fahrenheit
FEIS	-	Missouri River Master Water Control Manual Final Environmental Impact Statement
FEMA	-	Federal Emergency Management Agency
FIS	-	Flood Insurance Study
FPC	-	Federal Power Commission
ft	-	feet
FUI	-	Forecasted Ungaged Inflow
GIS	-	Geographic Information System
GOES	-	Geostationary Orbiting Environmental Satellite
GSA	-	General Service Administration
GWh	-	gigawatt hour
HEC	-	Corps' Hydrologic Engineering Center

HMS	-	Corps' Hydrologic Modeling System
Holdouts	-	Natural, or unregulated, flows
HQUSACE	-	Headquarters, U.S. Army Corps of Engineers
IMPLAN	-	Impact Analysis for Planning
I-O	-	input-output
IWIN	-	Interactive Weather Information Network
IWR	-	Institute for Water Resources
KAF	-	1,000 acre-feet
Kcfs	-	1,000 cubic feet per second
kW	-	kilowatt
kWh	-	kilowatt hour
LAN	-	Local Area Network
LRGS	-	Local Readout Ground Stations
LRS	-	Long-Range Study
M	-	million
Master Manual Master	-	Missouri River Water Control Manual
Master Manual Study	-	Missouri River Master Water Control Manual Review and Update Study
MAF	-	million acre-feet
MAPP	-	Mid-continent Area Power Pool
MBRFC	-	National Weather Service Missouri Basin River Forecast Center
MPE	-	Multi-sensor Precipitation Estimates
MRBA	-	Missouri River Basin Association
MRBC	-	Missouri River Basin Commission
MBIAC	-	Missouri River Basin Inter-Agency Committee
MBSA	-	Missouri Basin States Association
MBSC	-	Missouri Basin Survey Commission
MRBWMD	-	Missouri River Basin Water Management Division
MRD	-	Corps' Missouri River Division
MRADS	-	Missouri River Automatic Data System
MRNRC	-	Missouri River Natural Resources Committee
MOU	-	Memorandum of Understanding
mph	-	miles per hour
msl	-	mean sea level
MVD	-	Corps' Mississippi Valley Division
NWK	-	Corps' Kansas City District
NOW	-	Corps' Omaha District
MVP	-	Corps' St. Paul District
MVR	-	Corps' Rock Island District
MVS	-	Corps' St. Louis District
MW	-	megawatt
MWh	-	megawatt hour
NAGPRA	-	Native American Graves Protection and Repatriation Act
NHPA	-	National Historic Preservation Act
NPDES	-	National Pollutant Discharge Elimination System
NOAA	-	National Oceanic and Atmospheric Administration

NOC	-	Network Operations Center
NOHRSC	-	National Operational Hydrologic Remote Sensing Center
NRCS	-	Natural Resource Conservation Service
NRMS	-	Natural Resource Management System
NWCC	-	National Water and Climate Center
NWD	-	Corps’ Northwestern Division
NWS	-	National Weather Service
P.L.	-	Public Law
plover	-	piping plover
pp	-	powerplant
ppm	-	parts per million
POP	-	Points of Presence
PPCS	-	Power Plant Control System
QPF	-	Quantitative Precipitation Forecasts
RAS	-	River Analysis System
RCC	-	Reservoir Control Center
RDEIS	-	Revised Draft Environmental Impact Statement
RM	-	river mile
Service	-	U.S. Fish and Wildlife Service
SNOTEL	-	SNOw TELemetry
Southwestern	-	Southwestern Power Administration
SSARR	-	Streamflow Synthesis and Reservoir Regulation
Sq. Mi.	-	square miles
SWE	-	Snow Water Equivalency
System	-	Missouri River Mainstem Reservoir System
T&E	-	threatened and endangered species
tern	-	interior least tern
TLR	-	transmission loading relief
tw	-	tailwater
UMRS FFS	-	Upper Mississippi River System Flow Frequency Study
UNET	-	Unsteady Flow Through a Full Network
UPS	-	Uninterrupted Power Supplies
UTP	-	Unshielded Twisted Pair
USBR	-	Bureau of Reclamation
USGS	-	United States Geological Survey
Western	-	Western Area Power Administration
WAPA	-	Western Area Power Administration
WSCC	-	Western Systems Coordinating Council
WSFO	-	National Weather Service Weather Forecast Offices
yr	-	year

MISSOURI RIVER BASIN
MAINSTEM RESERVOIR SYSTEM
MASTER WATER CONTROL MANUAL

I – INTRODUCTION

1-01. **Authorization.** This manual has been prepared as directed in the U.S. Army Corps of Engineers' Water Management Regulation, ER 1110-2-240, which prescribes the policies and procedures to be followed by the U.S. Army Corps of Engineers (Corps) in carrying out water management activities, including establishment and the updating of water control plans for Corps and non-Corps projects, as required by Federal laws and directives. This manual is prepared as a Master Water Control Manual (Master Manual) as discussed in that regulation. This manual is also prepared in accordance with pertinent sections of the Corps' Engineering Manual, EM 1110-2-3600, entitled "Management of Water Control Systems." This Master Manual is prepared under the format and recommendations described in the Corps' Water Management Regulation, ER 1110-2-8156, dated August 31, 1995 and entitled "Preparation of Water Control Manuals." Revisions to this manual are processed in accordance with ER 1110-2-240. Deviations from this manual are processed in accordance with ER 1110-2-1400.

1-02. **Purpose and Scope.** Master Manuals for river basins that include more than one Corps District are prepared by, or under direct supervision of, Division Commanders. The system of six dams on the Missouri River affects not only the states within the Missouri River basin in which the six dams and their reservoirs are located, but also the downstream reaches of the Missouri River to its mouth near St. Louis, Missouri. The states are located within the Corps' Omaha and Kansas City Districts; therefore, the Missouri River Basin Water Management Division (MRBWMD), Programs Directorate, of the Corps' Northwestern Division (NWD) located in Omaha, Nebraska has prepared this Master Manual. A subset of the MRBWMD, known as the Reservoir Control Center (RCC), is responsible for the day-to-day regulation of the Missouri River Mainstem Reservoir System (System). Section 9 of the 1944 Flood Control Act authorized the System to be operated for the purposes of flood control, navigation, irrigation, power, water supply, water quality control, recreation, and fish and wildlife. In addition, operation of the System must also comply with other applicable Federal statutory and regulatory requirements. Furthermore, to achieve the multi-purpose benefits for which they were authorized and constructed, the six System reservoirs must be operated as a hydraulically and electrically integrated system. A Master Manual is required because the System consists of the integrated operation of multiple projects, each having its own Water Control Manual. The Master Manual serves as a guide to the RCC in meeting the operational objectives of the System when regulating the six System reservoirs. This Master Manual also includes the integrated operation of both System and tributary reservoir water control plans so that an effective plan for flood control and conservation operations exists within the basin. The sheer size of the System dwarfs all other tributary reservoir projects within the Missouri River basin; therefore, this plan must serve to integrate all those operations to remain effective in meeting the overall operational objectives of the System.

1-02.1. The total set of Water Control Manuals for the System numbers seven, one for each of the individual projects and this Master Manual. The Water Control Manual for the entire System is in seven volumes as follows:

Volume	Project
1	**Master Manual**
2	**Fort Peck Dam & Reservoir (Fort Peck Lake)**
3	**Garrison Dam & Reservoir (Lake Sakakawea)**
4	**Oahe Dam & Reservoir (Lake Oahe)**
5	**Big Bend Dam & Reservoir (Lake Sharpe)**
6	**Fort Randall Dam & Reservoir (Lake Francis Case)**
7	**Gavins Point Dam & Reservoir (Lewis and Clark Lake)**

1-02.2. The individual project Water Control Manuals serve as supplements to this Master Manual and present aspects of project usage not common to the System as a whole, including added detail on the incremental drainage areas regarding hydrology, hydrologic networks, forecasting, streamflow, and runoff. Also site-specific maps and regulation considerations for each individual project are discussed in greater detail than in this Master Manual.

1-02.3. This Master Manual describes the water control plan for the System. The plan consists of the water control criteria for the management of the System for the full spectrum of anticipated runoff conditions that could be expected to occur. According to ER 1110-2-240, “Throughout the life of the project, it is necessary to define the water control criteria in precise terms at a particular time, in order to assure carrying out the intended functional commitments in accordance with the authorizing documents.” Annual water management plans (Annual Operating Plans, or AOP’s) are prepared each year, based on the water control criteria contained in the Master Manual, in order to detail reservoir regulation of the System for the current operating year. Because the System is so large, it can respond to extreme conditions of longer than 1-year duration. The AOP document also provides an outlook for planning purposes in future years.

1-02.4. ER 1110-2-240 also specifies, “…necessary actions will be taken to keep approved water control plans up-to-date.” The regulation further states, “For this purpose, plans will be subject to continuing and progressive study by personnel in field offices of the Corps of Engineers.” Revision of this Master Manual may be necessary in the future because of the possible changing emphasis on the level of service to various authorized or new project purposes or with new knowledge that is gained from additional actual operating experience. The emphasis will remain, however, on maintaining the inherent flexibility that exists and is required for effective operation of the System. New information on the needs of the project purposes, such as the requirements for endangered species enhancement, may also require revision of the water control plan and, subsequently, the Master Manual. Furthermore, other factors within the basin, such as a significant reduction in the availability of water (changes in depletions of water within and downstream from the System), may also require a revision of the water control plan included in this Master Manual.

1-02.5. Chapter 3 of the Engineering Manual for Management of Water Control Systems (EM 1110-2-3600) outlines the various steps and technical considerations necessary to develop water control plans. This chapter states, "Usually, management of water control systems by the Corps involves input from other agencies of the Federal government, as well as State and local authorities, public utilities, irrigation districts, fish and wildlife interests, and other groups that are involved in environmental and public use functions of project regulation." ER 1110-2-240 also addresses public input when it states, "Water control plans will be developed in concert with all basin interests which are or could be impacted by or have an influence on project regulation." The NWD fully complied with these regulations and the Water Resources Development Act of 1990 as this Master Manual was reviewed and updated with a new water control plan. Basin interests can anticipate continued public involvement in the water control management process and any significant water control plan or Master Manual revisions in the future will be processed in accordance with ER 1110-2-240. Minor revisions to this or any of the previously mentioned individual project manuals will be the responsibility of the RCC and do not require coordination throughout the basin. In addition, changed circumstances or unforeseen conditions may necessitate short-term deviations from the current water control plans (CWCP). Such deviations are reviewed and approved by the Commander, Northwestern Division in accordance with ER 1110-2-1400.

1-03. **Related Manuals and Reports.** The Master Manual was first published in December 1960. Selected pages were revised in November 1973, and a revised water control manual was published in 1975. Regulation criteria for flood control were revised, and the Master Manual was republished in 1979. The Master Manual has been reprinted several times since with no additional changes using the 1979 date. The first Master Manual and its subsequent versions were developed in consultation with State governments within the Missouri River basin and Federal agencies having related authorities and responsibilities. This Master Manual represents the first major revision of the drought conservation regulation portion of the water control plan for the System.

1-03.1. Public concern over the drought conservation plan presented in the 1979 version of the Master Manual surfaced early in the 1987 to 1993 drought. This was the first major drought to occur in the basin since the System was originally filled and became fully operational in 1967. The NWD initiated an update of the water control plan in 1989 because of this concern. The update to the existing water control plan was considered a major revision that required extensive coordination with basin interests. As part of the subsequent review and update process for the Master Manual, an Environmental Impact Statement (EIS) under the auspices of the National Environmental Policy Act was prepared. Numerous supporting technical reports and five versions of the EIS (preliminary draft (May 1993), draft (July 1994), preliminary revised draft (August 1998), revised draft (August 2000), and final (March 2004)) were prepared. The basis for the selection of the water control plan included in this Master Manual is outlined in the Final EIS and the subsequent Record of Decision. There have been extensive coordination activities conducted by the NWD during the 14-year process of updating this Master Manual. This Master Manual represents the culmination of those coordination efforts.

1-03.2. The operation of the Corps' integrated dam and reservoir projects, such as the System, is guided by information presented in master water control manuals. To achieve the maximum multi-purpose benefits for which the Mainstem reservoirs were authorized and constructed, the System must be operated as a hydraulically and electrically integrated system. This Master Manual, therefore, presents the basic operational objectives and the plans to obtain these maximum multi-purpose benefits with supporting data. The individual project manuals for the System serve as supplements to this manual and present aspects of project usage not common to the System as a whole.

1-04. **Project Owner.** The System was constructed and is owned, operated, and maintained by the Corps of Engineers, Department of the Army.

1-05. **Operating Agency.** The Corps operates the System. The Corps' Northwestern Division's Missouri River Basin RCC, located in Omaha, Nebraska, oversees the day-to-day implementation of this water control plan. The Omaha District of the Northwestern Division has staff located at each of the System's projects to carry out the day-to-day operation (based on the water management orders received from the RCC in Omaha) and maintenance of the Mainstem projects. All of the Mainstem dams serve hydropower as an authorized function and, therefore, are automated into a system called the Power Plant Control System (PPCS) for regulation of hydropower production and project releases. The Western Area Power Administration (Western) uses the Mainstem projects as an integral part of the Midwest power grid. Project Power Production Orders, reflecting the daily and hourly hydropower limits imposed on project regulation, are generated by the RCC and sent to each Mainstem project on a daily basis, or more frequently, as required. Also during critical periods, coordination between project personnel and RCC staff is conducted on an as-needed basis to assure that expected releases rates are achieved.

1-06. **Regulating Agencies.** As the project owner, the Corps has the direct responsibility of regulating the System to meet the authorized project purposes. This is done in coordination with many others, including Federal, State and Tribal agencies and a myriad of stakeholders. As these other entities provide input to the Corps on the Master Manual and through the AOP processes, the Corps must determine if the proposal is within the Corps' authority and has met all applicable laws and regulations regarding System operation prior to incorporating any of this input into the AOP or day-to-day operations. As part of its regulation of the System, the RCC conducts day-to-day coordination with Western, which markets the power produced at each project, and frequent coordination with the U.S. Fish and Wildlife Service (Service), which advises the Corps on the effects of System regulation related to endangered and threatened species. Coordination with the other previously mentioned specific interest groups is conducted on an as-needed basis, following initiation by either the Corps or the entity.

II – LEGISLATIVE AND SYSTEM CONSTRUCTION HISTORY

2-01. **Water Resources Authorization History.** This section describes the authorization history of water resources projects in the Missouri River basin.

2-01.1. **Early Development.** The United States acquired the land that forms the Missouri River basin by a treaty signed on April 30, 1803. At more than 800,000 square miles in size, the Louisiana Territory was purchased for $15,000,000 from France and is called the Louisiana Purchase. The first Federal exploration/survey of the Missouri River basin was made in 1804-1806 by two Army officers, Captains Meriwether Lewis and William Clark. Development of the basin's water resources began in the 1800's with the earliest efforts being single-purpose developments in response to specific needs, such as use of the rivers for water supply, irrigation, navigation, or mining. The first steamboat entered the river in 1819, and traffic developed rapidly to meet the needs of the expanding West. The first Federal development was initiated when Congress appropriated funds to the Corps for a program of snag removal to aid navigation in 1824. Navigation of the Missouri River by steamboat reached a peak in about 1880 and dwindled to nothing by about 1890 because of the coming of the railroads. In 1884, at about the peak of steamboat traffic, Congress created the Missouri River Commission within the Corps for the purpose of improving the river channel and decreasing the transportation hazards. When the Commission ceased to exist in 1902, the Corps resumed its normal activities in the basin.

2-01.2. Prior to 1865, streamflow in the Missouri River basin was largely unused except for transportation by water and as a source of water supply. At about that time, the early settlers and homesteaders, their numbers swollen by uprooted Civil War survivors, began irrigation and mining ventures in substantial numbers. By the year 1900, streamflow depletions in the Missouri River basin, due to these private developments, had increased to about 3 million acre-feet (MAF) per year. Prior to 1900, Congressional legislation dealing with water resource development other than navigation was primarily concerned with support and encouragement of private development of water resources. This emphasis changed shortly after the turn of the century; and within the overall scope of the history of basin water resources development, several aspects of Federal legislation merit specific mention.

2-01.3. **The Reclamation Act of 1902.** This Act authorized development of irrigation projects with Federal financing subject to partial repayment by irrigators and partial reimbursement from hydroelectric power revenues. The Act is limited in application to the 17 states west of the 98th Meridian. The fundamental purpose of the Act was to reclaim and foster settlement on undeveloped lands in the western states. Accordingly, a limitation of 160 acres was placed on the amount of individually owned land that would be furnished irrigation water. The Reclamation Act has since been amended and expanded to permit water resources development for other beneficial purposes besides irrigation.

2-01.4. **The Rivers and Harbors Act of 1912.** This Act authorized a 6-foot navigation channel for the Missouri River from the mouth to Kansas City, Missouri. Several subsequent Congressional acts modified this navigation project, the latest being the Rivers and Harbors Act of March 2, 1945, which provided for works to secure a 9-foot-deep by 300-foot-wide channel from the mouth to Sioux City, Iowa.

2-01.5. **The Rivers and Harbors Act of 1927.** Pursuant to this Act, the Corps undertook the first comprehensive investigation and study ever made of the water resources and associated problems of the Missouri River basin. The entire river system was examined to determine the water resources and the prospects of its development for flood control, navigation, irrigation, and power. The reports of these investigations, the "308 Reports," are historic reference documents for water resource development in the Missouri River basin.

2-01.5.1. This comprehensive investigation and its reports identified many projects that did not appear to be feasible at that time or within the scope of National policy for Federal development but were subsequently adopted by the Corps and the Bureau of Reclamation (USBR) as integral parts of the Missouri Basin Plan. Experience was gained and a large amount of data was collected in diversified fields that have subsequently made important contributions to the solution of basin problems.

2-01.6. **The Rivers and Harbors Act of 1935.** The construction of Fort Peck Dam was commenced under Executive Order in October 1933 with funds provided by Congress for the relief of unemployment. Subsequently, the project was specifically authorized by Congress in the Rivers and Harbors Act, approved August 30, 1935, in accordance with the Chief of Engineers' recommendations included in House Document No. 238, 73rd Congress, 2nd Session. The Fort Peck Power Act of 1938 authorized construction of the power facilities. Originally, the project was authorized primarily for improving navigation on the Missouri River and the incidental purposes of flood control and hydroelectric power production. The Fort Peck Power Act of 1938 also designated the USBR as marketing agent for power generated and made power rate schedules subject to the confirmation and approval of the Federal Power Commission.

2-01.7. **The Flood Control Act of 1936.** This Act established the policy that (a) flood control on navigable waters or their tributaries is a proper activity of the Federal Government in cooperation with the States, and (b) the Corps' Chief of Engineers would have jurisdiction over, and supervision of, Federal investigations and improvements of rivers and other waterways for flood control and allied purposes. Subsequent flood control acts amended the 1936 Act to authorize Federal participation in more comprehensive water resources developments.

2-01.8. **The Flood Control Act of 1938.** Although this legislation resulted from studies of floods on the Mississippi River and did not authorize a large number of projects to be built in the Missouri River basin, it recognized the Missouri River basin as having a general flood problem in the lower portion of the basin and as contributing significantly to the disastrous floods on the Mississippi River. Accordingly, the Act authorized the Corps to construct nine reservoirs in the lower part of the Missouri River basin for flood control. The 1938 Act adopted comprehensive plans for many basins, including the Missouri River basin. This was the initial step toward the overall Missouri Basin Development Plan. The first expansion of this plan resulted from additional Corps studies and appeared in the Flood Control Act of 1941, wherein levee protection along the Missouri River from Sioux City, Iowa, to Kansas City, and the Harlan County Reservoir on the Republican River in Nebraska were authorized.

2-01.9. **The Flood Control Act of 1944.** This Act approved a plan of development for the Missouri River basin based on a Corps proposal, as presented in House Document No. 475, 78th

Congress, 2nd Session, and a proposal by the USBR, as presented in Senate Document No. 191, 78th Congress, 2nd Session. The coordinated result of these two plans was presented in Senate Document No. 247, 78th Congress, 2nd Session. Under this Act, the Corps was given the responsibility for development of projects on the main stem of the Missouri River. Tributary projects were made the responsibility of the Corps if the dominant purpose was flood control. The Department of the Interior was designated as the marketing agent for all power, beyond project requirements, produced at Corps projects. The Department of the Interior subsequently designated the USBR as the marketing agent for power generated by the main stem projects and the Southwestern Power Administration as the marketing agent for power generated at basin projects within the state of Missouri. Rate schedules for the sale of power are subject to confirmation and approval by the Federal Power Commission. Section l(b) of the Act, sometimes referred to as the O'Mahoney-Millikin Amendment, provides that, for water rising in states wholly or partly west of the 98th Meridian, use for navigation shall be subordinate to present or future beneficial consumptive use in those states. Under the 1944 Flood Control Act, approximately 100 tributary reservoirs were authorized in addition to the Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point projects on the main stem of the Missouri River. The Act incorporated the Fort Peck project into the multi-purpose Mainstem Reservoir System (System).

2-01.10. **The Watershed Protection and Flood Prevention Act of 1954.** This Act extended Federal interest and financial participation to land stabilization and flood prevention measures on smaller watersheds. Thus, this Act served to supplement the policy for flood control measures on major streams established earlier. Subsequent amendments to the Act of 1954 increased the limitations on size of watershed eligible for improvement and on storage capacity of individual reservoirs. These amendments also authorized provision of storage for purposes other than flood prevention, within the overall storage limitation.

2-01.11. **The 1958 Water Supply Act.** In this Act, Congress recognized that the States and local interests have primary responsibility for developing water supplies for domestic, municipal, industrial, and other purposes; however, it provided that the Federal Government should participate and cooperate by making provision for water supply in the construction, maintenance, and operation of Federal navigation, flood control, irrigation, or multiple-purpose projects. Accordingly, storage for water supply may be included in any Federally-constructed reservoir project, subject to consummation of certain assurances or agreements for non-Federal repayment of costs allocated to water supply.

2-01.12. **The Federal Water Project Recreation Act of 1965.** This Act established the development of the recreation potential at Federal water resource projects as a full project purpose.

2-01.13. **The 1986 Water Resources Development Act.** Section 906 of this Act establishes a comprehensive mitigation policy for water resource projects, including Section 906e, which authorizes the Secretary of Army to provide for fish and wildlife mitigation resulting in projects under his or her jurisdiction.

2-01.14. **Other Federal Legislation.** There is a significant amount of other Federal legislation of particular importance to land and water resources development in the Missouri River basin. This legislation has had a significant impact on water resources development and the implementation of the authorized purposes of the System and is, therefore, included here to provide additional understanding to the complexity of the System and the implementation of these laws into System regulation.

2-01.14.1. **The Fish and Wildlife Coordination Act of 1946.** This Act promotes the preservation and enhancement of fish and wildlife through equal consideration of their habitat needs in conjunction with Federal participation in water resource development commonly referred to as the "Coordination Act."

2-01.14.2. **The Federal Water Pollution Control Act of 1956 and subsequent amendments.** This Act provides for the preservation of water quality through low-flow augmentation.

2-01.14.3. **The Fish and Wildlife Coordination Act of 1958.** This Act provides that equal consideration should be given to fish and wildlife resources through consideration of their habitat needs in conjunction with Federal participation in water resource development. This Act also provides authority to modify projects for the benefit of fish and wildlife enhancement.

2-01.14.4. **The National Environmental Policy Act of 1969.** This Act outlines the actions to be taken relative to protecting and enhancing the quality of the human environment. In general, it requires that the impacts to the human environment be evaluated as a project is planned, with the impacts presented in an environmental impact statement. Further, this documentation needs to be coordinated with the public so that its comments are considered as the final project is selected.

2-01.14.5. **The Federal Water Pollution Control Act of 1972.** Referred to as the "Clean Water Act," this Act established goals to restore and maintain the quality of the Nation's waters. The effects of the regulation of the System on water quality are continuously monitored to ensure that the System regulation enhances water quality to the extent reasonably possible.

2-01.14.6. **The 1973 Endangered Species Act as amended.** The 1973 Endangered Species Act (Public Law 93-205 and as amended in Public Laws 95-632, 96-159 and 97-304) states the policy of Congress is that all Federal departments and agencies shall seek to conserve endangered and threatened species and shall utilize their authorities in furtherance of the purposes of this Act. The purposes of this Act are to provide a means whereby the ecosystems upon which endangered and threatened species depend may be conserved and to provide a program for the conservation of such endangered and threatened species. Section 7 states that all Federal departments and agencies shall, in consultation with and with the assistance of the Secretary of the Interior/Commerce, ensure that any actions authorized, funded, or carried out by them are not likely to jeopardize the continued existence of any endangered or threatened species or result in the destruction or adverse modification of habitat determined by the Secretary of Interior to be critical unless an exception has been granted by the Endangered Species Committee. The Fish and Wildlife Service (Service) of the Department of Interior administers consultation procedures. The System has both threatened and endangered species within the project area.

2-01.15. **Legislation of Significance to Tribes with Regard to System Regulation.** A number of Federal laws and regulations deal with impacts to Tribal resources and Federal Agency coordination and consultation requirements with Native American Tribes. Responsibilities toward Tribes in the Missouri River Basin are governed by a number of treaties, statutes, and executive orders. The treaties are not a grant of rights to the Tribes, but as the U.S. Supreme Court has said, it is a "grant of rights from them" *U.S. v. Winans*, 198 U.S. 371 (1905). The Tribes therefore retain any right that was not expressly extinguished in the treaty or later nullified by Congress. These rights, often called reserved rights, include water rights and traditional hunting and fishing rights. Some of the more significant laws that directly structure the Corps' relationship with Tribes include: the National Historic Preservation Act (NHPA, 16 U.S.C. § 470 *et seq*.), the Archaeological Resources Protection Act (ARPA, 16 U.S.C. §§ 470aa-mm), the Native American Graves Protection and Repatriation Act (NAGPRA, 25 U.S.C. § 3001 *et seq.*), and Executive Order 13007. These laws seek to protect Native American cultural resources, human remains, and sacred sites. They provide requirements and processes for the Corps to protect and preserve cultural resources. The statutes also provide a framework for consultation with Tribes on issues of mutual importance.

2-01.16. **Summary - Specific Project Authorizations.** The 1944 Flood Control Act authorized construction of all of the System projects with the exception of Fort Peck, which was originally authorized by the Rivers and Harbors Act of 1935. The inclusion of the Fort Peck project as part of the multipurpose System was authorized in the 1944 Flood Control Act. The Fort Peck Power Act of 1938 authorized construction of power facilities at the project while the 1944 Flood Control Act authorized multiple-purpose regulation of the Fort Peck project similar to the other System projects. As can be determined by reading the above Federal water resource legislative history, several acts influenced or guided the development of and/or regulation of the System and determined the operational objectives stated in this manual in the form of a water control plan for the System.

2-02. **Project Planning and Design History.** The following paragraphs provide a brief history of the planning and design of the System. This is best accomplished by reviewing the early days of water resource development in the Missouri River basin**.**

2-02.1. **The 1944 Flood Control Act.** The House Committee on Flood Control passed a resolution in 1943 asking the Corps to produce a plan for flood control and other purposes in the Missouri River basin. This request followed significant basin flooding in 1943, which is discussed in detail in Appendix A, titled Floods of 1943." Both the Corps and the USBR prepared plans for the multiple-purpose water resource management throughout the Missouri River basin. The Corps' then Missouri River Division Engineer, Colonel Lewis A. Pick, developed the Pick Plan, emphasizing navigation and flood control purposes. The Corps prepared a plan that relied heavily on a "308 Report" prepared in 1934. Three types of projects were proposed in the Pick Plan. These were 1,500 miles of levees along both sides of the Missouri River from Sioux City to the mouth, many small reservoirs located on the tributaries, and five additional Mainstem dams. William G. Sloan, Assistant Regional Director of the USBR's Upper Missouri Region, developed the Sloan Plan, emphasizing irrigation for economic stability and hydroelectric power for economic growth. Rivalry existed between the Corps and USBR over which of the two plans should be followed. A plan sponsored by the Corps (House Document No. 475, 78th Congress, 2nd Session) was submitted to the Congress on March 2,

1944. The USBR's plan was presented to the Congress on May 5, 1944, (Senate Document No. 191, 78th Congress, 2nd Session). A coordinated plan, developed by the Corps and USBR, was submitted to the Senate on November 21, 1944 (Senate Document No. 247). Franklin D. Roosevelt signed the Flood Control Act of 1944 on December 22, 1944 (Public Law 534, 78th Congress, 2nd Session), which approved the coordinated plan and authorized appropriations to each of the two agencies for initial construction.

2-02.2. **Missouri River Basin Project/Pick-Sloan Plan Missouri Basin Program.** The Missouri River Basin Project, authorized by the Flood Control Act of 1944, envisioned a comprehensive system of flood control, navigation improvement, irrigation, municipal and industrial water supply, and hydroelectric generation facilities for the 10 states in the Missouri River basin. As originally planned, the project was to include 213 single and multiple-use projects, providing 1.1 million kilowatts of hydroelectric capacity and irrigation for 5.3 million acres of farmland. Construction began when basin interests encouraged people to return to the Missouri River basin. This effort followed an exodus that began during the Great Drought of the 1930’s and extended through World War II, when people left for jobs in industrial centers on the east and west coasts. The plan was only partially completed; however, it completely changed water resource development in the basin. Congress passed legislation in 1970 to recognize the two visionary individuals who spearheaded the basin water resource planning by changing the project's name to the Pick-Sloan Missouri Basin Program.

2-03. **Mainstem Dam Construction History.** The Summary of Engineering Data -- Missouri River Mainstem System, Plates II-1 and II-2, present a summary of the significant dates of the System dams’ construction, diversion, closure, filling of the minimum operating pool, and initial generation of the first and last units. Plates II-3 through II-81 contain the pertinent details for each of the Corps’ System projects, including maps of each reservoir area, details of embankments, spillways, and outlet facilities, area-capacity tables, tail water curves; spillway-outlet works discharge capabilities; and power curves. A brief description of the significant construction dates of each of the six System projects is given in the following paragraphs. Additional project-specific construction details are provided in the individual project manuals. The dates that are given in these paragraphs and reflected in the Summary of Engineering Data are when the service availability was essentially complete. Service to navigation and flood control was initiated, to a limited extent, at the time closure of the dam was made. This service increased progressively to the in-service dates indicated when the project was essentially complete or full service to these authorized purposes was rendered by having a full System.

2-03.1. **Construction of Fort Peck Dam – Fort Peck Lake.** Fort Peck Dam is located on the Missouri River at river mile (RM) 1772 in northeastern Montana, 17 miles southeast of Glasgow, Montana and 9 miles south of Nashua, Montana. Construction of the Fort Peck project was initiated in 1933, embankment closure was made in 1937 as shown on Plate II-1. The project was regulated for the authorized purposes of navigation and flood control in 1938. The Fort Peck Dam embankment is nearly 4 miles long (excluding the spillway) and rises over 250 feet above the original streambed. Fort Peck Dam remains the largest dam embankment in the United States (126 million cubic yards of fill), the second largest volume embankment in the world, and the largest “hydraulic fill” dam in the world. Fort Peck Lake is the third largest Corps reservoir in the United States. When full, the reservoir is 134 miles long. The concrete spillway is over 1 mile long. In 1943, the first hydropower unit went on the line, and the third unit became operational in 1951, completing construction of the first powerplant. Construction of a second powerplant began in the late 1950's and the two units of this plant became operational in 1961. The Permanent Pool Zone (inactive storage) of the reservoir was initially filled (elevation 2150) in April 1942 and the Carryover Multiple Use Zone (elevation 2234) first filled in 1947, five years later. Drought conditions during the late 1950's, combined with withdrawals to provide water for the initial fill of other System projects, resulted in a drawdown of the reservoir level to elevation 2167.4 in early 1956, followed by a generally slow increase in pool elevation. The Carryover Multiple Use Zone was finally refilled in July 1964. Generally, it has remained filled from that time with the exception of the droughts of 1987 to 1993 and 1999 to date. Exclusive flood control storage space was first used in 1969, and then again in 1970, 1975, 1976, 1979, 1996, and 1997. In 1975, a maximum reservoir level of 2251.6 ft msl, 1.6 feet above the top of the Exclusive Flood Control Zone, occurred.

2-03.2. **Construction of Garrison Dam – Lake Sakakawea.** Garrison Dam is located in central North Dakota on the Missouri River at RM 1390, about 75 river miles northwest of Bismarck, North Dakota and 11 miles south of the town of Garrison, North Dakota. Construction of the project was initiated in 1946, closure was made in April 1953, and the navigation and flood control functions of the project were placed in operation in 1955. Garrison Dam is currently the fifth largest earthen dam in the world. The first power unit of the project went on the line in January 1956, followed by the second and third units in March and August of the same year. Power units 4 and 5 were placed in operation in October 1960. Lake Sakakawea first reached its minimum operating level in late 1955. Due to the drought conditions it was not until 10 years later, in 1965, that the Carryover Multiple Use Zone was first filled. Generally, it remained filled from that time through 2002, except for the two drought periods to date. Exclusive flood control storage space was used in 1969, 1975, 1995 and 1997. During 1975, all flood control space was filled and the maximum reservoir level was 0.8 foot above the top of the Exclusive Flood Control Zone, elevation 1854.8 ft msl. Lake Sakakawea is the largest Corps reservoir. When full, the reservoir is 178 miles long and up to 6 miles wide. The reservoir contains almost a third of the total storage capacity of the System, nearly 24 MAF, which is enough water to cover the state of North Dakota to a depth of 6 inches.

2-03.3. **Construction of Oahe Dam – Lake Oahe.** The Oahe Dam is located on the Missouri River at RM 1072, 6 miles northwest of Pierre, South Dakota. Construction of Oahe Dam was initiated in September 1948. Closure of the dam was completed in 1958, and deliberate accumulation of storage was begun in late 1961, just before the first power unit came on line in April 1962. The last of the seven power units became operational in July 1966. Permanent Pool storage space in Lake Oahe was first filled in 1962 and the Carryover Multiple Use Zone was filled in 1967. Generally, the Carryover Multiple Use Zone remained filled from that time through 2002, except for seasonal drawdowns in the interest of increased winter power generation and the two drought periods to date. The Exclusive Flood Control Zone in Lake Oahe was used in 1975, 1984, 1986, 1995, 1996, 1997, and 1999. The maximum of record elevation was experienced on June 25, 1995, at 1618.71 feet mean sea level (msl), when the Oahe pool occupied 1.7 feet of the 3-foot Exclusive Flood Control Zone. Lake Oahe is the second largest Corps reservoir, with just over 23 MAF of storage capability. When full, the reservoir is 231 miles long, with 2,250 miles of shoreline.

2-03.4. **Construction of Big Bend Dam - Lake Sharp.** Big Bend Dam is located on the Missouri River at RM 987, near Fort Thompson, South Dakota and about 20 miles upstream from Chamberlain, South Dakota. Lake Sharpe extends 80 miles upstream to the vicinity of the Oahe Dam. The project is basically a run-of-the-river power development with regulation of flows limited almost entirely to daily and weekly power pondage operations. Construction began in 1959, with closure in July 1963. The first power unit was placed on line in October 1964, and the last of the eight units began operation during July 1966. Since full operation began, the reservoir has been held very near the normal operating level of elevation 1420. A maximum level at elevation 1422.1, 0.1 foot into the Exclusive Flood Control Zone, occurred in June 1991.

2-03.5. **Construction of Fort Randall Dam – Lake Francis Case.** Fort Randall Dam is located on the Missouri River at RM 880, about 6 miles south of Lake Andes, South Dakota. Lake Frances Case extends to Big Bend Dam. Construction of the project was initiated in August 1946, closure was made in July 1952, initial power generation began in March 1954, and the project reached an essentially complete status in January 1956, when the eighth and final unit of the 320,000-kilowatt installation came into service. The reservoir filling was initiated in January 1953 and reached the minimum operating pool elevation of 1320 feet msl on November 24, 1953. The maximum reservoir level experienced to date was in July 1997, when an elevation of 1372.2 occurred, 2.6 feet below the top of the Exclusive Flood Control Zone. The maximum mean daily release of 67,500 cubic feet per second (cfs) was experienced in November 1997.

2-03.6. **Construction of Gavins Point Dam – Lewis and Clark Lake.** Gavins Point Dam is located on the Missouri River at RM 811 on the Nebraska-South Dakota border, 4 miles west of Yankton, South Dakota. Lewis and Clark Lake extends 37 miles to the vicinity of Niobrara, Nebraska. Construction was initiated in 1952, and closure was made in July 1955, with initial power generation beginning in September 1956. The third and final unit of the 100,000-kilowatt installation came into service in January 1957.

III – BASIN DESCRIPTION AND CHARACTERISTICS

3-01. **General Characteristics.** The Missouri River extends 2,619 miles from its source at Hell Roaring Creek and 2,321 miles from Three Forks, Montana where the Jefferson, Madison and Gallatin Rivers converge in southwestern Montana, near the town of Three Forks. The Missouri River is the longest river in the United States. The Missouri River flows generally east and south about 2,321 miles to join the Mississippi River just upstream from St. Louis, Missouri. The Missouri River basin has a total drainage area of 529,350 square miles, including about 9,700 square miles in Canada. That part within the United States extends over one-sixth of the Nation's area, exclusive of Alaska and Hawaii. It includes all of Nebraska; most of Montana, Wyoming, North Dakota, and South Dakota; about half of Kansas and Missouri; and smaller parts of Iowa, Colorado, and Minnesota. Plate III-1 shows a map depicting the shape of the Missouri River basin and identifying the location of the six Missouri River Mainstem Reservoir System (System) dams: Fort Peck, Garrison, Oahe, Big Bend, Fort Randall, and Gavins Point, including the major streams and tributaries.

3-01.1. The slope of the Missouri River averages 1.5 feet per mile, ranging from 4.3 feet per mile for the reach from Three Forks, Montana (head of the Missouri River) to above the falls at Great Falls, Montana, 3.7 feet per mile from below the falls to Zortman, Montana (near the head of the Fort Peck Reservoir), 1.1 feet per mile from Zortman to the Yellowstone River, and an average of 0.9 of a foot per mile from the Yellowstone River to the mouth at St. Louis, Missouri.

3-01.2 Grays Peak in Colorado is the highest point on the Continental Divide in the Continental United States and is located near the headwaters of the Platte River. At an elevation of 14,270 feet msl, Grays Peak is the highest point in the Missouri River basin. The lowest point in the basin is near the confluence of the Missouri River with the Mississippi River at St Louis, Missouri, with an elevation of 405 feet msl. The headwaters of the Missouri River are near Great Falls, which is at an elevation of 3,677 feet msl.

3-02. **Topography.** The Rocky Mountains form the basin's western boundary. They have an exceptionally rugged topography, with many peaks surpassing 14,000 feet in elevation. The mountains extend over an area of 56,000 square miles. The area contains many narrow valleys, but the peaks and mountain spurs dominate the area. Plate III-2 is a Missouri River basin map that shows the topographic features discussed below.

3-02.1. **Plains.** Sloping eastward from the Rocky Mountains, the Great Plains form the heartland of the basin. This broad belt of highlands covers approximately 370,000 square miles. The eastern boundary lies along the 1500-foot contour. The western boundary at the foot of the Rocky Mountains averages about 5,500 feet in elevation. West-to-east slopes average about 10 feet per mile. South and west of the Missouri River, the surface mantle and topography have been developed largely by erosion of a fluvial plain extending eastward from the mountains. North and east of the Missouri River, and even extending south of the river in some places, the Great Plains has been affected by continental glaciation. The topography here was shaped primarily by erosion of the glacial drift and till. Within the Great Plains, isolated mountainous areas were developed by erosion of dome-like uplifts. Principal among these are the Black Hills of western South Dakota and northeastern Wyoming, extending over an elliptical area 60 miles wide and 125 miles long.

3-02.2. **Central Lowlands.** The Central Lowlands border the Great Plains to the east, and often there is no perceptible line of demarcation between them. The Central Lowlands extend roughly from a line between Jamestown, North Dakota, and Salina, Kansas, eastward to the drainage divide between the Missouri and Mississippi Rivers. This entire area of 90,000 square miles was developed by erosion of a mantle of glacial drift and till. Coarser drift material covers the northern portion, while the finer till and loess is dominant in the southern portion.

3-02.3. **Ozark Plateau.** In the southeastern part of the basin in southern Missouri, an area of about 11,000 square miles of the basin lies in the Ozark Plateau. The topography here, developed by erosion of the Ozark uplift, is hilly to mountainous. Sedimentary formations with great depth underlie the moderate uplift, and only sedimentary rocks are left exposed. The basic surface material is limestone, and cavernous channels with spring flows abound in the area.

3-03. **Geology and Soils.** The Missouri River basin has a very diverse range of geology and soils. The geological history of the basin begins with the Precambrian Era, the oldest, and extends to the Cenozoic Era, the most recent. Many unique and rare geology formations are located in the Missouri River basin. The tectonic processes that formed the Rocky Mountains, the western border of the basin, are still active and continue to be present, e.g., volcanic activity, in Yellowstone Park. Plate III-2 shows the surficial geology and soils of the basin and identifies 24 different types of geological materials within the Missouri River basin. This map identifies the Missouri River's surficial geological properties. The floodplain and alluvial gravel terraces are colored mauve. At the lower end of the Missouri River, a gray area defines the Pre-Wisconsian drift for approximately 30 miles of the channel. The majority of the upper basin - western North and South Dakotas, central Montana, and northeastern Wyoming - is covered with shaley or sandy ground on the mixed sandstone and shale formations in the gold color. There are also small areas in Colorado and Kansas with the same type of deposits. Ice-laid deposits, outlined in blue, are thin and discontinuous and cover portions of the basin in the north and the east, beginning in Montana, across northern North Dakota and the eastern boundary of the basin. The surficial geological deposits in the south central portion of the basin have three dominate deposits: 1) the Pliocene-age and older stream deposits (dark purple); 2) the sand sheets (purple); and 3) the deeply weathered loess (aqua). The first two deposits extend from southwestern Wyoming, northeastern Colorado, and southern South Dakota across Nebraska and to north central Kansas. Two surficial geological deposits dominate the Missouri River basin's eastern boundary: 1) the Wisconsian loess (burgundy); and 2) the Pre-Wisconsian drift (gray). The geology of the basin's mountainous western boundary consists of diverse terrains of bedrock and rocky soils.

3-04. **Sediment.** In its natural state, the Missouri River transported a sediment load averaging 25 million tons per year in the vicinity of Fort Peck, Montana; 150 million tons per year at Yankton, South Dakota; 175 million tons per year at Omaha, Nebraska; and approximately 250 million tons per year at Hermann, Missouri, near its confluence with the Mississippi River. With the construction of each of the System and tributary dams, the reservoirs have acted as catchments for the tremendous load of sediment carried by the Missouri River and its tributaries. Approximately 18,000 to 26,000 acre-feet (KAF) of sediment enter each of the four largest System reservoirs each year. Approximately 90 KAF of sediment enters the System annually. The loss of reservoir storage capacity is currently approaching 5 percent of the original total System storage. Sediment is being deposited slightly below the prevailing reservoir pool levels. Most of the loss to the capacity to the Permanent Pool Zone occurred during the initial reservoir-filling period, prior to 1965. Since then, the storage loss has been occurring primarily in each reservoir's Annual Carry-over Multiple-Use Zone. All six System reservoirs have large deltas that have formed in their headwaters. These large sediment deposits continue to grow, although they are confined to the upper reaches of each reservoir and its major tributary arms.

3-04.1. In addition to sediment transported to the reservoirs by the Missouri River and its tributaries, some sediment enters the System reservoirs due to shoreline erosion processes. Reservoir shorelines are highly erodible because the river valley slopes are terraced and the soils consist of erodible sands, silts, clays, gravels, and shales. The thousands of miles of reservoir shorelines in the System reservoirs remain largely unprotected because the costs of protection are very high. Shorelines consisting of highly erodible soils and subjected to wave and ice action have experienced accelerated shoreline erosion in the form of slumping cut-banks. Erosion of the shorelines of the System reservoirs is expected to continue to some extent throughout the life of the projects. The slumping cut-bank material forms shelves of shallow water along the shorelines. The majority of eroded material usually remains immediately offshore, forming a very flat beach slope. As a result, the perimeters of the reservoirs are slowly becoming shallower and wider. In some cases, sediment moves along the shoreline in the direction of the prevailing wind or current and collects in deeper channels of tributary arms. Some tributary arms are filling and being cut off by these reservoir sediments and collapsing cut-banks.

3-05. **Basin Climate.** The broad range in latitude, longitude, and elevation of the Missouri River basin and its location near the geographical center of the North American continent, provide wide variations in climatic conditions. The climate of the basin is produced largely by interactions of three great air masses that have their origins over the Gulf of Mexico, the northern Pacific Ocean, and the northern Polar Regions. These great air masses regularly invade and pass over the basin throughout the year. The Gulf air tends to dominate the weather in summer and the Pacific and Polar air dominate in winter. This seasonal domination by the air masses and the frontal activity caused by their collisions produce the general weather regimes found within the basin. As is typical of a continental-interior plains area, the variations from normal climatic conditions, from season to season and from year to year, are very great. The outstanding climatic aberration in the basin during the 20th Century was the severe plains area drought of the 1930's when excessive summer temperatures and subnormal precipitation continued for more than a decade.

3-05.1. **Precipitation.** Normal average annual precipitation ranges from as low as 8 to 10 inches just east of the Rocky Mountains to more than 40 inches in the southeastern part of the basin and in parts of the Rocky Mountains. The pattern of average annual precipitation for the Missouri River basin is shown on Plate III-3. Prolonged droughts of several years' duration and frequent shorter periods of deficient moisture, interspersed with periods of abundant to excessive precipitation, are characteristic of the Great Plains.

3-05.1.1. **Cyclonic Activity.** Deep cyclones and accompanying frontal systems moving from the southern Great Plains states toward the northeast can cause widespread precipitation over the basin during all seasons of the year. This is due to the resulting influx of moist maritime tropical air from the Gulf of Mexico. Cyclonic activity over the basin is at a maximum during the late winter and early spring months. The cyclonic activity decreases to a minimum during the late summer and early fall months when the majority of precipitation results from air mass thunderstorms and orographic activity. The moisture-carrying ability of an air mass is dependent upon the temperature of the air mass and is normally at a maximum at mid-summer and at a minimum in mid-winter. The combination of moderate cyclonic activity and increased air mass moisture content that occurs during the spring and early summer months results in the normal seasonal precipitation maximum being observed throughout the basin during that time. Plates III-4 through III-7 illustrate the distribution of precipitation in the Missouri River basin for the months of April, May, June, and July, respectively. April is a transition month with mountainous areas and occasionally, the northern plains still in the grip of winter at the start of the month and the lower basin well into spring by late April. For most of the basin, June is the wettest month, with a sizable area of Kansas and Missouri receiving more than 5 inches of precipitation during an average year. July marks the start of dry weather for the inner mountain deserts of Wyoming and southern Montana.

3-05.1.2. **Summer Precipitation.** Precipitation during the late summer and fall months is usually of the short-duration thunderstorm type with small centers of high intensity. Widespread general rains occasionally occur, especially in the lower basin through October. A weak monsoonal moisture flow begins along the Front Range of the Rockies in Colorado in late July, which adds to precipitation amounts during July and August in the mountains around Denver, Colorado. Precipitation amounts during the months of August through October are generally less than those observed during the late spring and early summer in the basin, as noted on Plates III-8 through III-10.

3-05.1.3. **Winter Precipitation.** Winter precipitation usually results from the passage of well-developed low-pressure systems (cyclones) and active fronts. This precipitation occurs in the form of snow in the northern and central portions of the basin; however, it may occur in the lower basin states as either rain or snow or a mixture of both. Winter precipitation depths are, in general, considerably less than during other seasons of the year. This is due to the decreased moisture-carrying ability of the colder air masses and the barrier imposed by the Rocky Mountains to the westerly circulation that generally prevails through this season. The dry conditions are noted on Plates III-11 through III-15 for the months of November through March. Normally, the basin has fairly frequent light winter snows, interspersed with a few heavy storms. The average annual snowfall over the Great Plains increases from south to north. It ranges from under 12 inches in parts of the lower basin, to more than 36 inches in the eastern Dakotas, and to over 48 inches in the high plains areas in the west as shown on Plate III-16. High elevation stations in the Black Hills and in the Rockies along the western edge of the basin receive in excess of 100 inches of snowfall in many years. By late May, snow depths up to 6 feet, with a water equivalent of 2 feet, are not uncommon at mountain locations. Snow does not usually progressively accumulate over the plains, but is melted by intervening thaws. Exceptions have occurred in the northern plains, however, when snow that accumulated on the ground by the end of winter had water equivalent of 6 inches or more in some years. A map of maximum seasonal snowfalls encountered during the period 1961 to 1990 is shown on Plate III-17.

3-05.2. **Temperature.** Because of its mid-continent location, the basin experiences large temperature fluctuations and extremes. Winters are relatively cloudy and cold over much of the basin, while summers are fair and hot. Spring is normally cool, humid, and windy, while autumn is normally cool, dry, and fair. Temperature extremes range from winter lows of –60° Fahrenheit (F) in Montana to summer highs of 120° F in Nebraska, Kansas, and Missouri. The basin regularly experiences maximum temperatures above 105° F in parts of Kansas, Nebraska, and South Dakota in the summer and minimums below –30° F in the Rocky Mountains and on the plains of Montana and North Dakota. The temperature variability of the Missouri River basin is shown on Plates III-18 through III-21.

3-05.3. **Evaporation.** Average annual reservoir evaporation in the Missouri River basin varies from less than 2 feet in the western Rocky Mountains to over 6 feet in the plains area of western Kansas. Evaporation from the System reservoirs averages about 3 feet annually. For smaller reservoirs whose surface temperatures approximate air temperatures, most evaporation occurs during the April through October period; however, due to the large size of the System reservoirs, there is a considerable time lag between air temperatures and surface water temperatures. Also, because precipitation over the System reservoirs is normally at a maximum during the April-June period, net evaporation (evaporation less precipitation) is concentrated almost entirely in the July-December period. Normal annual net evaporation averages about 20 inches for the System as a whole, ranging from about 25 inches at Fort Peck to 17 inches at Gavins Point. A basin map showing average annual net reservoir evaporation is shown on Plate III-22.

3-05.4. **Wind.** Due to its mid-continent location, most extreme winds are caused by frontal passages and severe thunderstorm activity. While tornados produce the greatest wind speeds, they are short lived, are localized, and have little effect on reservoir elevation. Hurricanes do not reach the Missouri River basin, although cyclonic remnants of tropical storms occasionally reach the southern portions of Kansas and Missouri. On most reservoirs, winds capable of damaging riprap and eroding shorelines are those in excess of 45 miles per hour (mph) that are sustained for periods of an hour or more. In addition to generating significant waves with heights of 6 feet or more, sustained winds of that magnitude cause noticeable reservoir set-up or set-down, particularly when the winds blow along the long fetch of a shallow reservoir. Wind conditions at the System projects are monitored using anemometers on automated weather stations operated by the Corps, and real-time regional weather data can be accessed from the National Weather Service on the Internet.

3-06. **Basin Storm Potentialities and Major Basin Floods.** Approximately 130 Missouri River basin storms have been studied using the Corps' Storm Study Program. Of these 130 storms, 28 percent have occurred in the basin above Yankton and 72 percent below. None of the individual storms have been sufficiently extensive to encompass the entire basin. June has had the greatest number of occurrences, 38 percent of the total. In some areas of the country, surface dew-point temperatures are used as an index for the amount of moisture in a warm air mass from which precipitation falls. Records indicate that moisture charges during the major storms of record are all generally near the maximum of record. The source of moisture for all major storms in the basin is the Gulf of Mexico. Based on moisture potentialities alone, major storms would be most probable in late July or early August because normal and maximum recorded air mass moisture is the greatest during these months. Major storms throughout the Missouri River basin, however, result almost exclusively from conditions accompanying frontal systems. Since frontal passages are more numerous and more severe in May and June than in the dead of summer, major storms occur more frequently in late spring and early summer than at the time of maximum moisture charges in late July or early August.

3-06.1. Major storms do not provide a complete index to the probability of flood flows within the basin. Minor storms also may satisfy the infiltration capacities that exist in the basin, resulting in any additional rainfall contributing much larger volumes to streamflow than would have been the case if the ground had been relatively dry prior to the larger storm. Because of this, a continuing sequence of smaller storms, which may occur at any time of the year over portions of the basin, can also result in severe flooding. During the winter months, successive minor storms in the upper basin often result in a sufficient snow accumulation to cause the greatest flows of the year when the snow accumulation melts and appears as streamflow.

3-06.2. **Missouri River Floods.** Many instances of above-bankfull flows were experienced through the reach from Fort Peck Dam to the Platte River below Omaha prior to System regulation. Since regulation of System commenced, there would have been many more flood occurrences were it not for the upstream regulation. Regulation provided by the System, augmented by upstream tributary reservoir storage, has virtually eliminated significant flood flows on the Missouri River in this reach. Still, the System has not created a flood-free zone along the Missouri River for all conditions. Below the mouth of the Platte River, the incremental drainage area is of sufficient size that above-bankfull stages can continue to be expected as a result of flood runoff from major storms over the tributary areas, although significant stage reductions due to System regulation will usually occur.

3-06.2.1. All floods experienced in the upper basin except one have occurred in the March-July season, with snowmelt as an important flood component. The one exception occurred in 1923 when a large September rainstorm in southern Montana and northern Wyoming resulted in an early October Missouri River flood. Estimated crest discharges during this flood exceeded 100,000 cfs at Pierre, South Dakota and all upstream locations to the mouth of the Yellowstone River. In the lower Missouri River basin, floods have followed the same seasonal pattern observed in the upper basin; however, damaging floods have occasionally occurred prior to or following the normal March-July flood season, due mainly to heavy rainfall downstream. Crest stage and discharge data for past major Missouri River floods are summarized in Appendix A - Historic Floods and Flood Control Regulation Examples. Significant flood occurrences, with specific causative factors, are discussed in Appendix A – Floods.

3-07. **Runoff Characteristics.** Runoff into and downstream from the System varies in terms of the geographic distribution and seasonal fluctuation of the inflows. The distribution of streamflow in combination with extreme seasonal variation results in significant change. This variability requires a System water control plan that is very flexible to allow the Corps to meet the water resources mission and regulate the System to meet the operational objectives stated in this manual**.** Because the Missouri River basin is so large, individual basin descriptions and modeling parameters are available only in the six project water control manuals, Volumes 2 through 7, as described in Chapter II of this manual. Some general information is provided in the following paragraphs.

3-07.1. **Drainage Pattern.** The drainage pattern of the Missouri River basin and the locations of all of the Corps' civil work projects in the basin are shown on Plate III-23. Outstanding among the Missouri River's tributaries are: the Yellowstone River, which drains an area of over 70,000 square miles and enters the Missouri River near the Montana-North Dakota boundary; the Platte River, which has an 85,000 square mile drainage area that enters the Missouri in eastern Nebraska; and the Kansas River, which empties into the main stem of the Missouri River in eastern Kansas and drains an area of approximately 60,000 square miles. The most prominent feature of the drainage pattern of the upper and middle portions of the Missouri River basin is that every major tributary, with the exception of the Milk River, is a right bank tributary flowing to the east or to the northeast. Only in the lower basin, below Gavins Point Dam, is a fair balance reached between left and right bank tributaries. The direction of flow of the major tributaries is of particular importance from the standpoint of potential concentration of flows from storms that typically move in an easterly direction. The direction of flow is also important for another reason on the Yellowstone River because early spring temperatures in the western Yellowstone River basin in Montana range normally from 8 to 12 degrees F higher than along the northernmost reach of the Missouri River near Williston, North Dakota. This often results in ice breakup on the Yellowstone River prior to the time the ice goes out on the main stem of the Missouri River, thereby contributing to ice-jam flooding on the downstream reaches of the Yellowstone River and the Missouri River upstream from Lake Sakakawea.

3-07.2. **Streamflow Records.** The collection of systematic and continuous discharge records by the U.S. Geological Survey (USGS) in cooperation with the States, the Corps, and other agencies over most of the Missouri River basin has developed over the past three decades. Discharge records for stations on the Missouri River at Craig, Cascade, and Fort Benton, Montana are available since 1890, 1902, and 1910, respectively, and for the Yellowstone River at Glendive, Montana since 1903. Some records were obtained on the Missouri River at Williston, North Dakota during 1905 through 1907, at Bismarck, North Dakota during 1904-05, and at Kansas City, Missouri during 1905 and 1906. Aside from these, streamflow measurements at the present stations on the main stem of the Missouri River were not initiated until 1928. However, daily stage records for many of the Missouri River stations began in the 1870's. Systematic and continuous streamflow measurements at scattered tributary locations began much earlier than on the main stem, with some tributary records beginning in the early 1900's. Only a few locations have records prior to 1900.

3-07.2.1. During planning studies of the System in the 1940's, extension of the Missouri River discharge data prior to 1928 was considered to be essential. Accordingly, comprehensive studies were made and monthly streamflow data developed for selected stations through the period extending from 1898 to the initiation of the expanded streamflow measurement program that began in 1928. Because water use for all purposes has expanded significantly since settlement of the basin first began, adjustment of the records to represent a common level of water resource development was also considered necessary so that the flow data would be directly comparable from year to year. While any development level would have been satisfactory, the 1949 level was selected because it was just before the accelerated resource development that occurred in the Missouri River basin during the 1950's. Records accumulated since then have also been adjusted to the 1949 level for comparability purposes.

3-07.3. **Tributary Streamflow Characteristics.** Tributary streamflow characteristics vary widely across the basin depending on the location and source/type of associated runoff.

3-07.3.1. **Rocky Mountain Area.** Streams emanating from the Rocky Mountains are fed by snowmelt, are clear flowing and have steep gradients and cobble-lined channels. Stream valleys often are narrow in the mountains and widen out as they emerge from the mountains onto the out-wash plains. As shown on Plate III-24, mean annual runoff in terms of depth from the mountainous areas is high, exceeding 20 inches in some areas along the Continental Divide. Flood flows in this area are generally associated with the snowmelt period occurring in May and June. Occasionally, summer rainfall floods with high, sharp peaks occur in the foothills areas.

3-07.3.2. **Plains Area.** Streams flowing across the plains areas of Montana, Wyoming, and Colorado have variable characteristics. The larger streams with tributaries originating in the mountain areas carry sustained spring and summer flows from mountain snowmelt, and they have moderately broad alluvial valleys. Streams originating locally often are wide, sandy-bottomed, and intermittent, and they are subject to high-peak rainfall floods. Mean annual runoff from this upper plains area is low and variable, ranging from one-quarter to one-half of an inch. Streams in the plains region of the Dakotas, Nebraska, and Kansas, with the exception of the Nebraska sandhills area, generally have flat gradients and broad valleys. Except for the Platte River, most of the streams originate in the area and are fed by plains snowmelt in the early spring and occasional rainfall runoff throughout the warm season. Streamflow is erratic. Stream channels are small for the size of the drainage areas involved, and the flood potentials are high. When major rainstorms occur in the tributary area, streams are forced out of their banks onto the broad floodplains. Mean annual runoff is low, ranging from as little as one-quarter of an inch to 2 inches. In many of these streams, there may be no flow during drought periods. The streams generally are turbid, and they carry large suspended sediment loads during periods of high flow.

3-07.3.3. **Sandhills Area.** Streams originating in the Nebraska Sandhills, such as the Loup and Niobrara Rivers, are steady flowing, with much of the flow attributable to groundwater accretions. Floods are rare and they have relatively low peaks. Only a very small part of the Sandhills area contributes direct-flow runoff. The streams carry heavy loads of sand sediments, although they are relatively low in silt and colloidal sediments. Runoff, as measured streamflow, is higher than generally found in the adjoining plains areas, ranging up to 4 inches.

3-07.3.4. **Eastbank Streams.** Streams in the region east of the Missouri River have variable characteristics. Those in the Dakotas, such as the Big Sioux and James Rivers, are meandering streams with extremely flat gradients and very small channel capacities in relation to the areas drained. Drainage areas generally are covered with glacial drift, are extremely flat, and contain many pothole lakes and marshes. Rainfall in the spring often combines with the annual plains snowmelt to produce floods that exceed channel capacities and spread onto the broad floodplains. In late summer and fall, flows often drop to zero for extended periods. Streams in the eastern border region of Nebraska, Iowa, Missouri, and Kansas drain hard-soiled, hilly lands with relatively steep gradients and narrow valleys. Channels are deep and U-shaped. Flooding caused by high rainfall storms is frequent. Average annual runoff is high, ranging from 2 to 8 inches. Streamflow is generally turbid because of high concentrations of suspended sediments. Streamflow is somewhat more stable than in the plains area to the west, but the flow in many streams often approaches zero in late summer and fall.

3-07.3.5. **Ozark Highland Area.** Streams in the Ozark Highlands of Missouri resemble mountain streams with their clear, dependable base flows. Much of the area is underlain by limestone, and there are cavernous underground springs. The hilly terrain produces high-peak runoff, which contributes to frequent high-peak floods of large volume. Average annual runoff is high, ranging from 10 to 14 inches. High flows generally are experienced every year during the months of March, April, May, and June. Flows then normally recede, often to less than 15 percent of their average, during August, September, and October. Drainage areas are generally well timbered and sediment yields are normally small.

3-07.4. **Missouri River Flow Characteristics.** Unregulated Missouri River flows usually follow a definite and characteristic annual pattern, as illustrated by the monthly distribution of streamflows presented on Plates III-25 through III-27. Average flows, in general, increase from January to June and then gradually decrease through December. Historic maximum and minimum monthly mean flows at Sioux City are 187,000 cfs in April 1952 and 3,700 cfs in January 1940, respectively. At Kansas City, corresponding flows are 301,000 cfs in June 1908 and 5,000 cfs in January 1940. The "with reservoirs" graph on Plate III-25 and the data provided in Tables III-1 through III-5 illustrate the major changes in the monthly streamflow distribution that have occurred as a result of reservoir regulation. The Annual Flow Table, Table III-1, illustrates the extreme daily values since the System became operational, while the seasonal tables, Tables III-2 through III-5, show the distribution of flow according to the maximum and minimum monthly average flows. Although the general pattern of summer flows being higher than winter flows still prevails, System regulation serves to reduce summer flows in most years and to use the water stored to increase flows during the low-water periods of fall and winter.

3-07.4.1. **Winter Period.** In the upper portions of the basin, winter is characterized by frozen streams, the progressive accumulation of snow in the mountain areas, and intermittent snows and thaws in the plains areas. The season usually ends with a "spotty" snow cover of relatively low water content and a considerable amount of water in ice storage in the stream channels. Runoff in this period, which usually extends from late November into March, is quite low. In the lower basin, milder temperatures prevail during the winter months and considerable precipitation may occur in the form of rain or snow, which melts rapidly and contributes immediately to streamflow. This may occasionally result in substantial flows in this region, although winter runoff is usually quite low due to the relatively light amounts of precipitation that usually occur in this season. Intermittent freeze-up and break-up of river ice on both the main stem and the tributaries are common in the lower basin.

3-07.4.2. **Early Spring Period.** Early spring is marked by the rapid melting of snow and ice accumulations in the northern plains area, usually in March or April, accompanied ordinarily by very little rainfall. This causes the characteristic early spring ice breakup and an increase in streamflow, which is known as the early spring rise, or "March rise." Flood crests in the upstream reaches are flashy, particularly when associated with relatively sudden releases of ice jams. Ice jams are particularly severe in the Dakotas and on the lower Yellowstone River in Montana. The highest peak discharges and stages of record on the Missouri River from above the mouth of the Kansas River through the Dakotas have resulted from the spring break-up creating ice jam floods. Snowmelt in the mountains usually begins during this period, but contributes little to runoff until later in the year. Flows originating in the middle Missouri River basin generally from plains snowmelt are sometimes then augmented by rainfall in the lower basin during this period to produce flood flows in the lower Missouri River reaches.

3-07.4.3. **Late Spring and Early Summer.** Late spring and early summer are characterized by extensive general rains accompanied occasionally by severe local rainstorms and rapid melting of snow in the mountains. Peak runoff from these sources usually occurs in late May, June, or the first part of July. This results in the characteristic late spring rise, or "June rise," with peak discharges above Sioux City (except in the headwaters) usually less and volumes of runoff usually greater than during the early spring rise. A short interlude of moderately low discharges usually is experienced between the early spring and late spring rises. Occasionally, runoff from severe rainstorms in the upper plains area synchronizes with the high runoff from snowmelt and general rainfall in the mountains during this period. Runoff from rainstorms in the lower Missouri River basin during the months of May, June, and July have resulted in very severe Missouri River flooding below Sioux City during these months.

3-07.4.4. **Late Summer and Fall.** Late summer and fall are generally characterized by diminishing general rainfall, fairly frequent, widely scattered, and intense local rainstorms, and occasional severe storms. Flow in the upper Missouri River ordinarily decreases rapidly in late July from the previous high rates from mountain snowmelt. Flows decrease gradually, with an occasional rise, to the lower flows that prevail during winter. There are no records of great storms in this period having produced floods on the upper Missouri River anywhere near the magnitude of the fairly frequent early spring or late spring floods. Very severe floods have, however, occurred on tributaries during this period. Runoff originating in the lower basin usually decreases, although several large floods have occurred on the lower Missouri River due to severe floods emanating from the tributaries.

3-07.4.5. Mississippi River high flows could be adversely affected by reservoir regulation in the upper Missouri River basin. High stages on the Mississippi River, particularly below the confluence with the Ohio River, may be expected any time from January through July. The greatest floods of actual record have occurred in February and April-August on the Mississippi River. On the lower Missouri River, high flows have occurred in winter, but the main flood season extends from April through July. The greatest flood of record on the Missouri River occurred in July and exacerbated flooding on the Mississippi River. Discharges from the upper Missouri River basin during the early spring and late spring flood periods could, therefore, contribute substantially to lower Missouri and Mississippi River floods. From August to December, both the lower Missouri and Mississippi Rivers are usually characterized by low flows, much the same as the upper Missouri River; however, large storms or a sequence of lesser storms over the lower Missouri and Mississippi Rivers during this period have occasionally resulted in severe flooding.

Table III - 1
Annual Runoff Characteristics at Key Control Points

Key Control Point	Maximum Daily Discharge (cfs)	Minimum Daily Discharge (cfs)	Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	160,000	1,000	10,600	1968 - 2001
Fort Peck Outflow - Fort Peck, Montana	35,400	0	9,800	1968 - 2001
Missouri River at Wolf Point, Montana	45,100	680	10,100	1943 - 2001
Missouri River at Culbertson, Montana	69,200	575	10,300	1941 - 2001
Garrison Calculated Inflow	180,000	1,000	23,700	1968 - 2001
Garrison Outflow - Riverdale, North Dakota	65,200	4,100	22,500	1968 - 2001
Missouri River at Bismarck, North Dakota	68,800	4,000	23,000	1954 - 2001
Oahe Calculated Inflow	204,000	500	26,400	1968 - 2001
Oahe Outflow - Pierre, South Dakota	59,300	0	25,100	1968 - 2001
Big Bend Calculated Inflow	79,000	0	25,500	1968 - 2001
Big Bend Outflow - Ft. Thompson, South Dakota	74,300	0	25,100	1968 - 2001
Fort Randall Calculated Inflow	100,000	0	26,500	1968 - 2001
Fort Randall Outflow - Pickstown, South Dakota	67,500	0	26,100	1968 - 2001
Missouri River at Verdel, Nebraska	stage only station			
Gavins Point Calculated Inflow	74,000	4,000	29,000	1968 - 2001
Gavins Point Outflow – Yankton, South Dakota	70,100	6,000	28,900	1968 - 2001
Missouri River at Sioux City, Iowa	105,000	3,000	29,750	1953 - 2001
Missouri River at Omaha, Nebraska	116,000	2,440	33,280	1953 - 2001
Missouri River at Nebraska City, Nebraska	188,000	4,320	39,590	1953 - 2001
Missouri River at Rulo, Nebraska	289,000	4,420	42,470	1953 - 2001
Missouri River at Kansas City, Missouri	529,000	4,730	57,000	1958 - 2001
Missouri River at Waverly, Missouri	611,000	5,000	58,720	1958 - 2001
Missouri River at Jefferson City, Missouri	stage only station			
Missouri River at Boonville, Missouri	721,000	5,000	69,200	1958 - 2001
Missouri River at Hermann, Missouri	739,000	6,210	87,950	1958 - 2001

Table III - 2
Plains Snowmelt (March, April, and May) Flows

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	37,400	4,900	13,300	1968 - 2001
Fort Peck Outflow - Fort Peck, Montana	18,700	3,200	8,630	1968 - 2001
Missouri River at Wolf Point, Montana	27,200	1,180	9,310	1943 - 2001
Missouri River at Culbertson, Montana	32,800	1,350	10,200	1941 - 2001
Garrison Calculated Inflow	69,600	11,000	27,400	1968 - 2001
Garrison Outflow - Riverdale, North Dakota	38,500	10,300	20,900	1968 - 2001
Missouri River at Bismarck, North Dakota	42,000	9,200	22,400	1954 - 2001
Oahe Calculated Inflow	68,700	12,800	30,300	1968 - 2001
Oahe Outflow - Pierre, South Dakota	53,000	1,200	21,400	1968 - 2001
Big Bend Calculated Inflow	54,900	1,600	22,200	1968 - 2001
Big Bend Outflow - Ft. Thompson, South Dakota	53,800	2,100	22,000	1968 - 2001
Fort Randall Calculated Inflow	60,200	5,200	24,700	1968 - 2001
Fort Randall Outflow - Pickstown, South Dakota	53,700	3,500	22,000	1968 - 2001
Missouri River at Verdel, Nebraska	stage only station			
Gavins Point Calculated Inflow	59,600	10,700	26,200	1968 - 2001
Gavins Point Outflow - Yankton, South Dakota	59,500	10,800	26,000	1968 - 2001
Missouri River at Sioux City, Iowa	88,000	9,140	30,300	1953 - 2001
Missouri River at Omaha, Nebraska	93,800	10,200	35,400	1953 - 2001
Missouri River at Nebraska City, Nebraska	99,000	15,300	44,700	1953 - 2001
Missouri River at Rulo, Nebraska	106,000	15,400	48,500	1953 - 2001
Missouri River at Kansas City, Missouri	149,000	20,200	67,200	1958 - 2001
Missouri River at Waverly, Missouri	168,000	19,200	69,400	1958 - 2001
Missouri River at Jefferson City, Missouri	stage only station			
Missouri River at Boonville, Missouri	235,000	19,500	85,700	1958 - 2001
Missouri River at Hermann, Missouri	333,000	22,800	115,000	1958 - 2001

Table III - 3
High Mountain Snowmelt (June, July, and August) Flows

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	43,600	4,100	13,700	1968 - 2001
Fort Peck Outflow - Fort Peck, Montana	35,000	4,700	10,500	1968 - 2001
Missouri River at Wolf Point, Montana	36,300	1,170	10,600	1943 - 2001
Missouri River at Culbertson, Montana	37,050	1,270	10,500	1941 - 2001
Garrison Calculated Inflow	85,900	7,600	33,600	1968 - 2001
Garrison Outflow - Riverdale, North Dakota	61,800	11,100	24,900	1968 - 2001
Missouri River at Bismarck, North Dakota	64,600	8,440	25,000	1954 - 2001
Oahe Calculated Inflow	61,100	15,400	28,200	1968 - 2001
Oahe Outflow - Pierre, South Dakota	56,500	4,200	30,200	1968 - 2001
Big Bend Calculated Inflow	55,100	5,000	30,200	1968 - 2001
Big Bend Outflow - Ft. Thompson, South Dakota	54,700	4,500	29,800	1968 - 2001
Fort Randall Calculated Inflow	58,300	6,000	31,400	1968 - 2001
Fort Randall Outflow - Pickstown, South Dakota	60,700	2,600	31,900	1968 - 2001
Missouri River at Verdel, Nebraska	stage only station			
Gavins Point Calculated Inflow	65,000	8,500	34,500	1968 - 2001
Gavins Point Outflow - Yankton, South Dakota	64,400	8,000	34,000	1968 - 2001
Missouri River at Sioux City, Iowa	66,400	23,300	36,200	1953 - 2001
Missouri River at Omaha, Nebraska	78,600	26,900	40,600	1953 - 2001
Missouri River at Nebraska City, Nebraska	118,000	29,900	47,300	1953 - 2001
Missouri River at Rulo, Nebraska	165,000	29,800	51,100	1953 - 2001
Missouri River at Kansas City, Missouri	288,000	33,800	69,100	1958 - 2001
Missouri River at Waverly, Missouri	306,000	34,400	71,600	1958 - 2001
Missouri River at Jefferson City, Missouri	stage only station			
Missouri River at Boonville, Missouri	375,000	36,600	82,000	1958 - 2001
Missouri River at Hermann, Missouri	376,000	39,500	99,900	1958 - 2001

Table III - 4
Fall Runoff (September, October and November) Flows

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Lake Calculated Inflow	17,300	4,400	7,770	1968 - 2001
Fort Peck Lake Outflow - Fort Peck, Montana	21,600	3,000	9,100	1968 - 2001
Missouri River at Wolf Point, Montana	29,100	2,330	11,000	1943 - 2001
Missouri River at Culbertson, Montana	28,600	1,130	10,400	1941 - 2001
Lake Sakakawea Calculated Inflow	33,500	7,500	17,500	1968 - 2001
Lake Sakakawea Outflow - Riverdale, North Dakota	49,400	9,900	21,000	1968 - 2001
Missouri River at Bismarck, North Dakota	48,200	8,120	21,800	1954 - 2001
Lake Oahe Calculated Inflow	48,600	10,700	22,400	1968 - 2001
Lake Oahe Outflow - Pierre, South Dakota	56,100	6,100	27,200	1968 - 2001
Lake Sharpe Calculated Inflow	77,600	6,100	27,800	1968 - 2001
Lake Sharpe Outflow - Ft. Thompson, South Dakota	56,200	5,400	26,900	1968 - 2001
Lake Francis Case Calculated Inflow	56,700	5,900	27,000	1968 - 2001
Lake Francis Case Outflow - Pickstown, South Dakota	66,700	5,400	34,000	1968 - 2001
Missouri River at Verdel, Nebraska	stage only station			
Lewis and Clark Lake Calculated Inflow	69,600	7,800	36,400	1968 - 2001
Lewis and Clark Lake Outflow - Yankton, South Dakota	70,000	7,500	36,200	1968 - 2001
Missouri River at Sioux City, Iowa	71,600	6,950	34,800	1953 - 2001
Missouri River at Omaha, Nebraska	75,000	8,300	37,400	1953 - 2001
Missouri River at Nebraska City, Nebraska	79,400	14,400	41,600	1953 - 2001
Missouri River at Rulo, Nebraska	83,900	17,000	43,800	1953 - 2001
Missouri River at Kansas City, Missouri	135,000	20,600	56,100	1958 - 2001
Missouri River at Waverly, Missouri	142,000	21,600	56,700	1958 - 2001
Missouri River at Jefferson City, Missouri	stage only station			
Missouri River at Boonville, Missouri	188,000	24,600	65,200	1958 - 2001
Missouri River at Hermann, Missouri	287,000	29,400	79,200	1958 - 2001

Table III - 5
Winter Runoff (December, January, and February) Flows

Key Control Point	Maximum Monthly Average Discharge (cfs)	Minimum Monthly Average Discharge (cfs)	3-Month Average Daily Discharge (cfs)	Period of Record
Fort Peck Calculated Inflow	16,200	3,800	7,970	1968 - 2001
Fort Peck Outflow - Fort Peck, Montana	15,200	5,300	11,300	1968 - 2001
Missouri River at Wolf Point, Montana	15,800	995	9,620	1943 - 2001
Missouri River at Culbertson, Montana	17,400	1,010	9,940	1941 - 2001
Garrison Calculated Inflow	31,800	8,600	16,800	1968 - 2001
Garrison Outflow - Riverdale, North Dakota	33,700	12,900	23,600	1968 - 2001
Missouri River at Bismarck, North Dakota	34,800	5,880	23,000	1954 - 2001
Oahe Calculated Inflow	37,000	12,900	25,200	1968 - 2001
Oahe Outflow - Pierre, South Dakota	36,100	12,300	21,200	1968 - 2001
Big Bend Calculated Inflow	36,600	11,700	21,300	1968 - 2001
Big Bend Outflow - Ft. Thompson, South Dakota	35,400	12,100	21,200	1968 - 2001
Fort Randall Calculated Inflow	38,400	12,400	22,500	1968 - 2001
Fort Randall Outflow - Pickstown, South Dakota	32,400	5,900	16,100	1968 - 2001
Missouri River at Verdel, Nebraska	stage only station			
Gavins Point Calculated Inflow	30,600	9,300	18,700	1968 - 2001
Gavins Point Outflow - Yankton, South Dakota	37,100	10,400	19,000	1968 - 2001
Missouri River at Sioux City, Iowa	39,900	6,290	17,400	1953 - 2001
Missouri River at Omaha, Nebraska	44,300	8,160	19,600	1953 - 2001
Missouri River at Nebraska City, Nebraska	52,400	10,200	24,600	1953 - 2001
Missouri River at Rulo, Nebraska	57,400	10,000	26,300	1953 - 2001
Missouri River at Kansas City, Missouri	77,700	13,000	35,200	1958 - 2001
Missouri River at Waverly, Missouri	79,800	13,000	36,500	1958 - 2001
Missouri River at Jefferson City, Missouri	stage only station			
Missouri River at Boonville, Missouri	106,000	13,800	43,900	1958 - 2001
Missouri River at Hermann, Missouri	179,000	17,100	61,500	1958 - 2001

3-07.5. **Missouri River Sediment Characteristics.** In its natural state, the Missouri River transported a sediment load increasing from an average of 25 million tons per year in the vicinity of Fort Peck, Montana to 150 million tons per year at Yankton, South Dakota, 175 million tons per year at Omaha and approximately 250 million tons per year at Hermann, Missouri near its confluence with the Mississippi River. With the construction of each of the System dams, beginning with the closure of Fort Peck Dam in 1936, the sediment entering each of the respective reservoirs was trapped. The flow released from the reservoirs was clear and essentially free from sediment, and the downstream load was derived from downstream tributary contributions and from material eroded from the bed and banks of the river. Currently, the

Missouri River from the headwaters of the Fort Peck to Gavins Point Dam near Yankton is almost fully controlled by the System dams. Beginning at Gavins Point Dam, the lowermost dam, the main stem of the Missouri River begins anew as a sediment-free stream. It begins immediately to derive a new load from erosion of the bed and banks and from tributary streams; however, the current sediment transport in the river from the Gavins Point Dam to the mouth is but a small portion of its previous load. Analysis of the sediment transport in the Missouri River at Omaha shows that the load presently is composed of about 70 percent sand-size material; whereas, this fraction was only about 30 percent of the total prior to closure of the upstream dams and armoring of the channel bank below Sioux City. Subsequent to closure of Fort Randall Dam in 1952, the total suspended load at Omaha has been relatively consistent at approximately 25 million tons per year, versus the prior to dam construction previous long-term average of 175 million tons per year. At the mouth of the Missouri River near St. Louis, the total suspended sediment load now is about one-half the load experienced prior to closure of the System and tributary dams.

3-07.5.1. Sediment that deposits in the upper portion of a reservoir, or the headwaters, forms a delta over time. As sediment continues to deposit, the delta grows into the reservoir and can create problems. As deposition occurs in the reservoir, storage space for water is lost as a result of the process. A secondary result of this is that the volume of water that a project was once able to capture is reduced. Multiple storage zones in the reservoir are impacted in this manner. As deposition occurs in the headwaters, the main channel loses its transport capacity, be it water and/or sediment. This, in turn, raises that water surface level while making shallow channel depths, which present two more prominent problems, increased flood stages and increased groundwater elevations. As deposits have grown in size and extended down into the lakes, they have blocked boat ramps and even cut off reservoir arms. Boat ramps are often concentrated in lake arms, as are fish spawning and rearing habitat. Other common problems include mosquito infestation and weed development.

3-08. **Missouri River Basin Land Use.** The Missouri River basin's total land area in the United States totals about 328 million acres. Agriculture accounts for 95 percent of this area, while the remainder is devoted to recreation, fish and wildlife, transportation, and urban uses. Well over half of the total, 180 million acres, is pasture and range grassland devoted primarily to grazing. Cropland comprises nearly 104 million acres, or 32 percent of all lands basin wide, but the proportion ranges from as high as 71 percent in eastern Nebraska and western Iowa to as low as 7 percent in the Yellowstone River basin. Irrigated lands in the basin comprise 7.4 million acres, with about 6.9 million acres intensively cropped and about 0.5 million acres in irrigated pasture. Forest and woodland areas, most of which are grazed, total about 28 million acres, which is about 9 percent of the basin area. Transportation, urban development, and related uses now consist of 8 million acres of land. Water areas cover 3.9 million acres. Although they represent only 1.2 percent of the total basin area, the rivers, lakes, reservoirs, farm ponds, and other bodies of water are extremely important to the basin's overall economy.

3-08.1. **Land Treatment Considerations.** Individual farmers have practiced conservation practices for many years, and since 1933, the Natural Resource Conservation Service (NRCS) (formerly the Soil Conservation Service) has encouraged these practices by providing incentive payments. Projects constructed enhance soil and water conservation by increasing the infiltration and water holding capacity of the soil, providing for surface water storage and stabilizing water disposal systems through such measures as terracing, contouring, strip cropping, grassed waterways, stabilization structures, crop rotation, pastures, and woodlands. Accomplishments of these programs in the Missouri River basin now include land treatment measures for gully-erosion control, grade stabilization, and flood damage reduction.

3-08.1.1. The forestry program of the Department of Agriculture also affects the water resources of the Missouri River basin. A large portion of the runoff appearing as streamflow in the upper Missouri River basin originates in the forested mountain areas. The forestry program includes the cutting of merchantable timber in a manner that will break up extensive, dense stands but maintain partial cover and provide for reproduction, thinning of even-aged stands of young timber, tree planting in denuded areas for timber production and erosion prevention, forest management for increased snow catch and water, intensification of fire and disease prevention, and construction of improvements incidental to the foregoing.

3-09**. Missouri River Basin Population.** Approximately 12 million people live in the Missouri River basin according to 1990 census information. Plate III-28 shows the population distribution by county in the basin. The basin is primarily rural but does contain several large population urban centers and medium sized cities. Many of the larger cities are located on the Missouri River.

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IV – MISSOURI RIVER BASIN FEDERAL PROJECTS AND RIVER REACH DESCRIPTIONS

4-01. **Missouri River Basin - Mainstem System Reservoirs.** The Missouri River Mainstem Reservoir System (System) is comprised of six reservoirs that were constructed by the Corps of Engineers. These six Corps reservoirs contain about 73.4 million acre-feet of storage capacity, which constitutes over 52 percent of the total storage in the basin's 17,200-plus reservoirs. The System is the largest reservoir system in the United States. It contains 71 percent of the installed capacity in the basin's Federal hydroelectric power system, provides almost all of the reservoir support for downstream flow support on the Missouri River, and contributes greatly to flood protection for over 2 million acres of land in the floodplain of the Missouri River. At normal pool levels, these reservoirs provide an aggregate water surface area of 1 million acres for recreation and fish and wildlife enhancement.

4-02. **Authorized Purposes of the Mainstem Reservoir System.** The six System dams are regulated as a hydrologically and electrically integrated system for the Congressionally authorized purposes of flood control, navigation, hydropower, water supply, water quality, irrigation, recreation, and fish and wildlife. The 1944 Flood Control Act authorized construction of the System dams, with the exception of Fort Peck Dam, which was authorized by the Rivers and Harbors Act of 1935. The Fort Peck Power Act of 1938 authorized the construction of hydropower facilities at Fort Peck Dam. The 1944 Flood Control Act also recognized that all of the authorized purposes for the other System projects should apply to Fort Peck as well as making this project a part of the System. The Endangered Species Act of 1973 (Public Law 93-205, as amended in Public Laws 95-632, 96-159 and 97-304) states that the policy of Congress is for all Federal departments and agencies to seek to conserve endangered and threatened species and to utilize their authorities in furtherance of the purposes of the Act. This Act is discussed in greater detail in Chapter II, Paragraph 2-01.14.6 of this Master Manual. The System has endangered species and has, therefore, operated for the continued existence of these species in coordination with the Service. This Missouri River Mainstem System Master Water Control Manual presents the guidelines and operational objectives for regulating the System for the Congressionally authorized purposes, with recognition that other incidental benefits are also achieved.

4-03. **System Project Locations.** The Corps has six multiple purpose dams located on the main stem of the Missouri River. Extending from the upper reaches of Fort Peck Lake in northeastern Montana to Gavins Point Dam in southeastern South Dakota and northeastern Nebraska, the reservoirs control runoff from 279,480 square miles of the upper Missouri River basin. A map of the Missouri River basin with the main stem and tributary projects is shown on Plate III-23. A Summary of Engineering Data containing pertinent project information is shown on Plates II-1 and II-2.

4-03.1.1. Fort Peck Dam is located at river mile (RM) 1771.5 in McCone and Valley Counties, Montana, 17 miles southeast of Glasgow and 9 miles south of Nashua. The western boundary of the 57,500 square mile drainage area is the Continental Divide.

4-03.1.2. The next downstream project is Garrison Dam at RM 1389.9 in Mercer and McLean Counties, North Dakota. Garrison Dam is 75 river miles northwest of Bismarck, the state capital, and 11 miles south of the town of Garrison, North Dakota. The primary tributary, the Yellowstone River, enters the Missouri River at RM 1582, about 14 miles above the headwaters of Lake Sakakawea.

4-03.1.3. Oahe Dam is located at RM 1072.3 in Stanley and Hughes Counties, South Dakota, 6 miles northwest of Pierre, the capital. The Cheyenne River, draining southwestern South Dakota and northeastern Wyoming, is the largest tributary. Other major tributaries include the Moreau, Grand, Cannonball, Heart, and Knife Rivers.

4-03.1.4. Big Bend Dam, at RM 987.4, is near Fort Thompson, South Dakota and about 20 miles upstream from Chamberlain, South Dakota in Buffalo and Lyman Counties. The primary tributary is the Bad River, which enters the Missouri River at Fort Pierre, South Dakota in the upper end of Lake Sharpe.

4-03.1.5. Fort Randall Dam, also in South Dakota, is located in Charles Mix and Gregory Counties at RM 880.0, about 6 miles south of Lake Andes, South Dakota. The major tributary, the White River, enters Lake Francis Case at RM 955.

4-03.1.6. The last dam, Gavins Point Dam, is on the South Dakota-Nebraska state line at RM 811.1, 4 miles west of Yankton, South Dakota. The right abutment and powerhouse are located on the Nebraska side in Cedar County. The left abutment is in Yankton County, South Dakota. The Niobrara River, a right bank tributary, enters the Missouri River about 8 miles above the headwaters of Lewis and Clark Lake.

4-04. **System Project Physical Components.** The following paragraphs describe the embankments, spillways, outlet works, hydroelectric powerplants, and water supply facilities for each of the System projects. Plates II-3 through II-81 contain maps of each project, including details of embankments, spillway, outlet works and powerplant facilities, area-capacity tables, tailwater rating curves, spillway and outlet works discharge rating curves, and powerplant characteristics.

4-04.1. **Fort Peck Dam – Fort Peck Lake.** The following paragraphs describe the physical features of the System project, Fort Peck Dam – Fort Peck Lake.

4-04.1.1. **Fort Peck Embankment.** Fort Peck Dam is 4 miles long and was constructed almost entirely by hydraulic fill methods. The final topping out of the embankment and a section at the end of a 2-mile-long dike are rolled-earth construction. The embankment contains more than 122 million cubic yards of dredged fill material, making Fort Peck Dam one of the largest hydraulic fill dams in the world. Maximum height of the embankment is 250.5 feet msl, and the maximum base width is 3,500 feet. The crest elevation of the embankment is at 2280.5 feet msl, and the crest width is 50 feet. Rock riprap protects the upstream face of the embankment above elevation 2162 feet msl. A continuous sheet pile cutoff wall in an impervious core provides seepage control. Relief wells are placed along the downstream toe to reduce hydrostatic pressure in the shale foundation.

4-04.1.2. **Fort Peck Spillway.** The Fort Peck spillway is a massive concrete and steel structure located in a natural saddle of the reservoir rim, about 3 miles east of the dam. It consists of a partially lined approach channel; a gated control structure, including a training wall section; a lined discharge channel; and an unlined earth discharge channel that enters the Missouri River about 9 river miles below the dam. Seventeen concrete gate piers are set on a curved line support and provide mountings for 16 vertical lift spillway gates. The piers also support a steel service bridge, a reinforced concrete highway bridge and piers, machinery platforms, and service walkways. The spillway gates, each 25 feet high and 40 feet wide, are electrically operated and can be individually controlled from the service bridge. The spillway crest elevation is 2225 feet msl. Discharge capacity at the maximum operating pool elevation of 2250 feet msl is 230,000 cfs.

4-04.1.3. The concrete-lined discharge channel is about 5,000 feet long and varies in width from 800 feet at the end of the spillway gate structure to 120 feet at the downstream end. A reinforced concrete cutoff structure is located at the downstream end of the discharge channel. This structure extends about 70 feet below the channel floor and has wide wing walls to control erosion on the adjacent shale banks. The spillway does not have an energy dissipation structure. Spillway releases have enlarged and deepened a natural stilling basin that has formed immediately downstream from the cutoff structure. Foundation rebound has caused differential movement of the gate structure, spillway channel, sidewalls, and roadway retaining walls. Foundation rebound at the downstream section of the spillway chute has resulted in deformation of the channel floor. There is a concern that any future sustained spillway releases may erode around the west wing wall or uplift the floor slabs and threaten the downstream end of the spillway channel.

4-04.1.4. **Fort Peck Outlet Works and Power Tunnels.** Four concrete diversion tunnels, varying in length from 5,700 to 7,200 feet, extend through the east abutment. A submerged intake structure equipped with removable steel trash racks is located at the upstream end of the tunnels. The intake floor of the tunnel portals is at elevation 2030 feet msl. Emergency and main control shafts are located near the axis of the dam. Each tunnel has two 48-ton vertical lift tractor type emergency gates 11 feet wide and 24 feet high. Tunnels 1 and 2 have steel liners downstream from the control shafts to supply flows to Powerplants 1 and 2, respectively. Flow through these tunnels is controlled in Powerhouse 1, which contains Powerplant 1, and the main control shafts, having no regulating gates, serve as auxiliary surge tanks. Tunnels 3 and 4 were designed for emergency flood releases. Two cylindrical gates are installed in each of the main control shafts of Tunnels 3 and 4 for flow control. The upper main control gates are at elevation 2165 feet msl and the lower gates are at elevation 2085 feet msl. Total discharge capacity of both Tunnels 3 and 4 at elevation 2250 feet msl is 45,000 cfs. The flood control tunnels have not been used in some years. Because of experience gained during past release periods, the flood control tunnels should not be operated at individual tunnel release rates above 5,000 cfs without an updated evaluation from the Corps' Omaha District of the effects from such an operation. Past occurrences of cavitation, violent surging, loud noises, gate icing, and gate vibration have resulted in a reluctance to use these structures as a primary solution to project releases greater than powerplant capacity. Since 1975, supplemental releases above powerplant capacity have been made over the spillway. The Omaha District requested authority within the Major Rehabilitation program for replacement of the Fort Peck flood control gates; however, authorization to implement the recommendations in the study was not approved. The tunnels discharge into a concrete reinforced stilling basin consisting of retaining walls, training walls, outlet portals, base slab, and baffle piers.

4-04.1.5. **Fort Peck Powerplants.** Powerplant 1 is located on the left bank of the discharge channel approximately 260 feet downstream from the Tunnel 1 portal in Powerhouse 1. The original Powerplant 1 penstock system was determined to be unsafe in a March 1988 Omaha District reconnaissance report. Replacement of the original penstock, trifurcation, unit penstocks, and butterfly valves was completed in 1992. The turbines are vertical–shaft, Francis-type turbines with plate steel scroll cases. Discharge capacity at rated head is 8,800 cfs. Units 1 and 3 have a nameplate rating of 43.5 megawatts (MW) and the smaller Unit 2 is rated at 18.25 MW. All three units were rewound in 1978, but the Unit 3 stator experienced a major failure in February 2002 and will be rewound. An enclosed surge tank section houses three interconnected 40-foot diameter surge tanks. New, more restrictive orifices were installed in the 8-foot diameter surge tank risers during the penstock replacement to prevent surge tank overtopping. The control room for both powerplants is located in Powerhouse 1.

4-04.1.5.1. Powerplant 2 has two identical turbine generator units located approximately 350 feet downstream from the Tunnel 2 portal. Two penstocks extend from a wye branch at the outlet end of the tunnel. An enclosed surge tank structure houses two interconnected surge tanks. Vertical–shaft, Francis turbines are connected to generators having nameplate ratings of 40 MW each. Units 4 and 5 became operational in 1961, and no rewinds have been required. The discharge capacity of Powerplant 2 is 7,200 cfs.

4-04.1.5.2. Each powerplant has a separate switchyard with a tie line for power interchange between the powerplants. Generation from Powerplant 1 is transmitted to either the east or west grid. Units 1 and 3 are important to the Western Area Power Administration for load control on the west grid. Powerplant 2 supplies energy to the east grid only.

4-04.1.6. **Fort Peck Water Supply Facilities.** Water supply for the town of Fort Peck is obtained from a 10-inch raw water line that taps into the Unit 3 penstock. A water filtration treatment plant is located near the town site.

4-04.2. **Garrison Dam – Lake Sakakawea.** The following paragraphs describe the physical features of the System project, Garrison Dam – Lake Sakakawea.

4-04.2.1. **Garrison Embankment.** Garrison Dam is a rolled earth fill embankment, 11,300 feet long at the crest, rising 210 feet above the old riverbed to a crest elevation of 1875 feet msl. The maximum dam base width is 3,400 feet and the crest width is 60 feet. The upstream portion of the embankment is composed of impervious material and the downstream portion is semi-pervious with a pervious drainage blanket over the old streambed. Seepage control is accomplished by a combination of the upstream pervious blanket, steel sheet piling cutoff walls, impervious filled cutoff trenches, grout curtains at the abutments, and a toe drain in the downstream section of the embankment. Relief wells located about 175 feet downstream from the toe of the dam reduce hydrostatic pressure in the foundation. The upstream face of the dam is protected from wave action by riprap placed above elevation 1800 feet msl. A gravel blanket extends from the bottom of the riprap to elevation 1770 feet msl.

4-04.2.2. **Garrison Spillway.** The 1,336-foot wide Garrison spillway is sited along the left abutment and is separated from the main embankment by about 800 feet of natural ground. It is a conventional concrete chute type with crest gates at the upper end and consists of the approach channel, control gate structure, lined chute, stilling basin, and unlined discharge channel. The spillway crest, at elevation 1825, consists of an ogee weir divided into 28 bays. Each bay contains a tainter gate 40 feet wide by 29 feet high. The gates are electrically operated and can be individually controlled from the service bridge. The concrete lined discharge chute extends 2,600 feet downstream from the crest structure to the stilling basin. The stilling basin is 800 feet wide and 200 feet long with a floor elevation of 1620 feet msl. Baffles located in the lower end of the stilling basin are 10 feet high and 8 feet wide, spaced on 10-foot centers. Discharge capacity at maximum operating pool (elevation 1854 feet msl) is 660,000 cfs. An unlined pilot channel will erode and guide flows to the Missouri River channel in the event spillway releases are required.

4-04.2.3. **Garrison Outlet Works and Power Tunnels.** The outlet works and power tunnels include an approach channel, an intake structure, eight concrete lined tunnels (three for flood control and five to supply the power units), a stilling basin at the downstream end of the flood control tunnels, and a discharge channel. A large reinforced concrete intake structure contains gate-controlled inlets to the eight tunnels through the dam. Each flood control tunnel has an 18-foot wide by 24.5-foot high tainter gate for flow regulation. Two 12-foot wide by 26-foot high vertical lift gates are located near the upstream end of the five power tunnels. Emergency gates are provided for closure ahead of each of the regulating gates. Tunnels 1 through 5 are concrete with a 29-foot inside diameter and serve as conduits for 24-foot diameter 1,829-foot long steel penstocks to the power units. Tunnels 6, 7, and 8 are for flood control and discharge into a stilling basin. Stop log slots are located in the upper end of the stilling basin for dewatering. Tunnel 6 has an inside diameter of 26 feet and Tunnels 7 and 8 have inside diameters of 22 feet. The combined discharge capacity of Tunnels 6 through 8 is 98,000 cfs at elevation 1854 feet msl. A discharge channel extends nearly 4,000 feet from the downstream edge of the tailrace to the Missouri River channel.

4-04.2.4. **Garrison Powerplant.** In addition to the five penstocks described above, the powerplant has two surge tanks per unit, each 65 feet in diameter and nearly 140 feet high. The powerhouse contains five generators, turbines, control room, and related equipment. The five units have a 41,000-cfs discharge capacity at 150 feet of rated head. A major rehabilitation of the Garrison powerplants was approved, and construction began in 2000 to install more efficient stainless-steel turbine runners. The main unit transformers are located on the transformer deck on the downstream side of the powerhouse and supply power to the switchyard by a high-voltage, oil-filled, pipe cable system. The Garrison switchyard is located southeast of the powerhouse between the outlet works discharge channel and the downstream slope of the dam. The estimated cost of the powerplant major rehabilitation is $55 million. An additional $20 to 30 million may be spent on switchyard rehabilitation. Nameplate rating of Units 1, 2 and 3 will increase from 109.25 MW to 126 MW and Units 4 and 5 will remain at 109.25 MW unless further modifications are made. Maximum efficiency of the turbines' efficiency is expected to be near 95 percent.

4-04.2.5. **Garrison Water Supply Facilities.** A 12-inch water line supplies the town of Riverdale and the Corps' maintenance facility. The Garrison National Fish Hatchery is located downstream from Garrison Dam and receives water from a 16-inch line extending from the Units 4 and 5 penstocks.

4-04.3. **Oahe Dam – Lake Oahe.** The following paragraphs describe the physical features of the System project, Oahe Dam – Lake Oahe.

4-04.3.1. **Oahe Embankment.** Oahe Dam is a compacted earthen embankment flanked by massive shale berms, both upstream and downstream. Outlet works tunnels are located in the right abutment and power tunnels in the left abutment. The total embankment length excluding the spillway is 9,300 feet, maximum dam height is 245 feet, maximum dam base width is 3,500 feet, dam crest width is 60 feet and top of dam elevation is 1660 feet msl. The total dam fill volume is approximately 92 million cubic yards. The right abutment and central valley portions of the embankment are composed of both impervious materials placed in the upstream third of the embankment and more pervious materials placed in the downstream remaining section of the embankment. The left abutment portion is composed of mostly impervious materials. An impervious blanket was placed in the upstream berm and a 5,270-foot long steel sheet pile wall was constructed 350 feet upstream of the axis of the embankment to control under seepage. The upstream embankment slope is provided rock protection that extends to the crest. A system of 34 relief wells is used in conjunction with a sheet pile cutoff wall to control hydrostatic seepage in the embankment foundations.

4-04.3.2. **Oahe Spillway.** The Oahe spillway is located about 1 mile from the right abutment of the dam. An unlined approach channel was excavated in shale to elevation 1590 feet msl for a distance of approximately 1,200 feet upstream from the spillway gate structure. The spillway structure has a flat weir with a crest elevation of 1596.5 feet msl. Eight tainter gates, each 50 feet wide by 23.5 feet high, provide control. A depressed basin extends 100 feet downstream from the weir and a paved apron extends another 210 feet downstream from the end sill of the basin. The spillway has never been used and provision for a conventional spillway chute and stilling basin has been deferred. An unlined discharge channel extends approximately two miles downstream from the spillway structure. Spillway operating criteria have been established to reduce unpaved discharge channel erosion rates and are published in the Oahe Project - Missouri River Mainstem System Reservoir Regulation Manual. The discharge capacity of the spillway is 80,000 cfs at maximum operating pool.

4-04.3.3. **Oahe Outlet Works.** The outlet works consist of an approach channel, six tunnels with intake structures and control shafts, a stilling basin, and a discharge channel. The approach channel and outlet tunnels were used for diversion of Missouri River flows during construction of the embankment. The intakes are individual, submerged reinforced structures located at the upstream end of the tunnels. They are staggered in plan and elevation. Intake 1 is set the furthest upstream and has the lowest invert elevation (1425 feet msl). Each succeeding intake is approximately 70 feet farther downstream with the invert elevation raised in 6-foot increments. The six flood control tunnels are parallel to each other, with a centerline spacing of 85 feet and lengths varying from 3,500 to 3,660 feet. The control shafts are located near the axis of the dam and house the control and emergency gates and other equipment necessary for flow control. The six control gates include a 13-foot by 22-foot vertical lift cable suspended tractor-type gate installed in each of Tunnels 1 to 4 and a 13-foot by 22-foot hydraulic lift, wheeled-type gate installed in Tunnels 5 and 6 for fine regulation. A single 13-foot by 22-foot vertical lift tractor-type emergency gate is provided for use in any of the six tunnels. The combined discharge capacity of the six tunnels is 111,000 cfs at elevation 1620 feet msl. The stilling basin downstream from the tunnel portals consists of training piers, drop sections, retaining walls, weir baffles, and end sill. An ogee weir divides the stilling basin into a double stage type with a primary basin and a secondary basin. Two rows of concrete baffles, 6 feet high, are located in the secondary basin, with the tops of the baffles at the same elevation as the end sill. A discharge channel approximately 9,000 feet long returns flow to the Missouri River.

4-04.3.4. **Oahe Powerplant.** The powerplant intake structure, located near the left abutment, has seven intake towers spaced 90 feet on centers. Each tower contains a cylinder gate, 10 feet high and 30 feet in diameter, to control the water passing through eight openings into a 30-foot diameter shaft that connects with a tunnel at the bottom. Bulkhead platforms are provided on the outside of the towers at elevation 1620 feet msl for installing bulkheads. The seven power tunnels extend from the downstream edge of the intake structure to the upstream face of the surge tank base structures. They vary in length from 3,280 to 4,000 feet and are curved in plan. The downstream portions of the tunnels are steel lined, extending from the terminus of the concrete lined section near the axis of the dam to the downstream edge of the tunnel entry structure. Seven 24-foot inside diameter steel penstocks extend 294 feet from the embedded liner to the spiral case. Two, 70-foot diameter by 145-foot high surge tanks are provided for each penstock. The seven hydraulic turbines are vertical-shaft, single–runner, Francis–type turbines, with welded-steel scroll cases and elbow-type draft tubes. The powerhouse discharge capacity at rated head is 54,000 cfs. The generators were rewound from May 1984 through December 1986 and have a nameplate rating of 112.29 MW at a 0.95 power factor. They have been designed to operate at 115 percent of nameplate. Transformer banks are installed in vaults on the draft tube deck. The switchyard, located on the right tailrace, contains an autotransformer section, 115 kV bays, and 230 kV bays. The tailrace is paved with reinforced concrete anchored to the foundation. The tailrace discharge channel is 508 feet wide and extends 1,200 feet downstream from the lower end of the tailrace paving.

4-04.3.5. **Oahe Water Supply Facilities.** A pumping station was constructed for the USBR Oahe Diversion but not used since that project was deauthorized. The intake for the Mni Wiconi pipeline is located about four miles downstream from the dam at Channel Block 6 and does not affect Oahe releases.

4-04.4. **Big Bend Dam – Lake Sharpe.** The following paragraphs describe the physical features of the System project, Big Bend Dam – Lake Sharpe.

4-04.4.1. **Big Bend Embankment.** Big Bend Dam is a rolled earth fill embankment with the powerhouse at the right abutment and the spillway at the left abutment. The total embankment length, including the spillway, is 10,570 feet. Maximum dam height is 95 feet, top elevation is 1440 feet msl, maximum dam base width including berms is 1,200 feet and the top of dam width is 50 feet. The embankment makes a gentle S-curve across the valley and is composed of approximately 17 million cubic yards of fill material. The embankment is built on dredged pervious fill which has a top elevation near 1357 feet msl. A central impervious core along the entire length of the dam extends from the pervious fill to 5 feet below the top of the dam to control seepage through the embankment. An impervious blanket ties into the central impervious core and extends 425 to 540 feet through the major portion of the embankment. A pervious drain section is located on the downstream side of the impervious core.

4-04.4.2. **Big Bend Spillway.** The Big Bend spillway structure is 376 feet wide and is sited at the left end of the embankment section. The spillway structure consists of an ogee weir with a crest elevation 10 feet above the bottom of the approach channel, eight 40-foot wide by 38-foot high tainter gates, a highway bridge, equipment platforms, and service walkways. The gates operate individually and may be opened or closed in 1-foot increments. A concrete chute extends from the spillway weir to the stilling basin, which is 194 feet long, including the end sill. The end sill is stepped in 5-foot increments from elevation 1320 to 1330 feet msl. Two rows of concrete baffles having a top elevation of 1332 feet msl are provided in the stilling basin. The discharge capacity is 268,000 cfs at elevation 1423 feet msl.

4-04.4.3. **Big Bend Outlet Works.** There are no conventional outlet works structures at the Big Bend project. Releases must be made through the powerplant or the spillway.

4-04.4.4. **Big Bend Powerplant.** The right bank Big Bend powerhouse has a curved approach channel to the intake structure containing separate intakes for each of the eight turbines. Unit intakes are divided into three water passages by intermediate piers. Each water passage contains two sets of gate slots, one for the service gate and one for the bulkhead gate. Three tractor-type, vertical-lift, service gates are provided for each of the unit intakes. An emergency bulkhead-type gate is provided for use in any of the upstream bulkhead gate slots. The powerhouse is constructed integrally with the intake structure. Eight vertical-shaft, fixed–blade, propeller-type turbines with concrete semi-spiral cases and concrete elbow-type draft tubes are installed in the powerhouse. Their combined discharge capacity is 103,000 cfs at a rated head of 67 feet. Generators 1, 2, and 3 were rewound in 1990 and 1991 and have a nameplate rating of 67.276 MW. Units 5 through 8 have the original windings and have a nameplate rating of 58.5 MW. Each pair of generators is connected to one of the four main power transformers located on the draft tube deck. The high voltage switching facilities are also located on the draft tube deck. The reinforced concrete tailrace is 675 feet wide and 140 feet long. The tailrace discharge channel extends 4,350 feet downstream from the downstream end of the tailrace paving.

4-04.4.5. **Big Bend Water Supply Facilities.** There are no water supply facilities provided from the Big Bend powerhouse.

4-04.5. **Fort Randall Dam – Lake Francis Case.** The following paragraphs describe the physical features of the System project, Fort Randall Dam – Lake Francis Case.

4-04.5.1. **Fort Randall Embankment.** Fort Randall Dam is a rolled earth fill embankment with a 165-foot maximum height and a 10,700-foot length, including the spillway section. The top of dam elevation is 1395 feet msl; fill volume, including berms, is approximately 50 million cubic yards; maximum dam base width is 4,300 feet; and the top of dam width is 60 feet. Rock-fill riprap protection is provided for the upstream earth fill slopes above elevation 1310 feet msl. The embankment section primarily consists of a central impervious earth fill section and dumped chalk fill outer berm sections. An upstream impervious fill blanket adjacent to the central impervious section reduces uplift pressures beneath the embankment by lengthening the seepage path. Seepage through and beneath the valley embankment section is controlled primarily by the massive embankment and berm sections and by pressure relief wells along the downstream toe of the compacted embankment. There is no dam cutoff for seepage control.

4-04.5.2. **Fort Randall Spillway.** The spillway is a conventional chute-type spillway located near the left abutment of the dam. A large ravine upstream from the dam, supplemented by a relatively small amount of unlined excavation, forms the approach channel. The spillway structure has an ogee crest weir having a crest elevation of 1346 feet msl, concrete piers, 21 40-foot wide by 29-foot high tainter gates, a roadway, service bridge, and machinery platforms. The gates operate individually and can be opened or closed in 1-foot increments. A 1,000-foot wide paved chute connects the spillway weir to the stilling basin. The stilling basin has an end sill stepped at 5-foot increments from elevation 1198 to 1218 feet msl. The spillway discharge channel is paved for 75 feet downstream from the end sill of the stilling basin. Discharge capacity at the maximum operating pool elevation, 1375 feet msl, is 508,000 cfs.

4-04.5.3. **Fort Randall Outlet Works and Power Tunnels.** The outlet works are located near the left abutment, approximately 800 feet riverward of the spillway structure, and include eight tunnels for powerplant releases and four tunnels for supplemental releases. The reinforced concrete intake structure consists of twelve towers spaced on 70-foot centers and rising about 180 feet above the chalk foundation. Each tower has two 11-foot by 23-foot service gates and two emergency gates to control flow into the tunnels. A 49-foot transition connects the two 11-foot by 23-foot conduits in each tower with the 22-foot diameter tunnels. Access to the intake structure is via a service bridge connecting the gantry deck to the highway on the main embankment. Tunnels 1 through 8 are used for power discharges and Tunnels 9 through 12 are for releases supplemental to the powerplant. A fine-regulating gate was provided near the lower end of Tunnel 10 but failed during an extended period of high releases in 1975 and was not replaced. Prior to gate vibration studies in 1998 and 1999, the cable-suspended service gates were operated in a fully open position when supplemental releases were required during the fall drawdown of Lake Francis Case. The study determined that the gates could be safely operated at partial gate openings, and this was done for the first time in the Fall of 1999 with Tunnel 11. The eight power tunnels and former regulating Tunnel 10 are 22 feet in diameter for the first 215 feet downstream from the transition section connecting the intake structure with the tunnels. The remainder of each of these tunnels is 28 feet in diameter. Steel penstocks 22 feet in diameter are installed in the downstream portion of the power tunnels and Tunnel 10. Flood control Tunnels 9, 11, and 12 are 22 feet in diameter throughout their entire length. The stilling basin extends approximately 730 feet downstream from the tunnel portals and consists of a retaining wall on the landward side, a training wall separating the stilling basin and tailrace, and a series of baffle piers between these two walls. An ogee weir divides the stilling basin into an upstream primary basin and a downstream secondary basin. The ogee weir crest is at elevation 1244 feet, or approximately 25 feet above the primary floor basin. It extends 400 feet across the full width of the basin. Three concrete training piers extend approximately 200 feet downstream from the tunnel portals and function to separate flows from the four flood control tunnels. Two rows of baffle piers are placed across the width of the secondary basin, with the piers in each row staggered with respect to those in the other row. An end sill and cutoff wall are located at the downstream end of the basin. The discharge capacity of the flood control tunnels is 128,000 cfs.

4-04.5.4. **Fort Randall Powerplant.** Eight 59-foot in diameter by 100-foot high surge tanks are located upstream from the powerhouse and are connected in pairs to the penstocks serving each of Units 1, 3, 5, and 7. The penstocks without surge tanks are connected to turbines with slow-acting governors and the penstocks with surge tanks are connected to turbines with fast-acting governors. Eight vertical-shaft, single-runner Francis-type hydraulic turbines with steel spiral casings are installed in the powerhouse. The discharge capacity of the turbines is 44,500 cfs at a rated head of 112 feet. The generators, operational since 1954 to 1956, have a nameplate rating of 40 MW and have not been rewound. The tailrace is approximately 560 feet wide and extends 500 feet downstream from the powerhouse. The sidewall on the right bank is the switchyard retaining wall and the sidewall on the left is the boundary wall between the tailrace and stilling basin. An outdoor switchyard contains the main transformers, switchgear, main high voltage busses, circuit breakers, transformers, disconnects, lightning arresters, and instrument transformers. The Omaha District submitted a Major Rehabilitation Report in March 2002 that recommended replacement of the turbine runner and generator rotor, upgrade of the generators to 59 MW, and replacement of other powerhouse and switchyard equipment. The estimated cost of the selected plan is $137 million.

4-04.5.5. **Fort Randall Water Supply Facilities.** There are no water supply facilities provided from the Fort Randall powerhouse.

4-04.6. **Gavins Point Dam – Lewis and Clark Lake.** The following paragraphs describe the physical features of the System project, Gavins Point Dam – Lewis and Clark Lake.

4-04.6.1. **Gavins Point Embankment.** Gavins Point Dam is a rolled earth fill embankment 8,700 feet in length, including the spillway. The powerhouse is located at the right abutment and the spillway is located on the riverward side of the powerhouse, separated by an unexcavated portion, Chalk Island. The embankment contains approximately 7 million cubic yards of fill material obtained from the spillway, powerhouse, and downstream-channel excavations. The embankment crest is at elevation 1234 feet msl, maximum height above the streambed is 74 feet, and average height above the valley floor is 60 feet. A core and a blanket, extending 300 feet upstream from the core, were constructed from impervious material. Downstream relief wells and the level of Lake Yankton, located immediately downstream from the dam, control hydrostatic pressures.

4-04.6.2. **Gavins Point Spillway.** The Gavins Point spillway is a chute-type spillway consisting of a short approach channel, a gated-ogee crest structure, a concrete-paved chute, a stilling basin, and a discharge channel. The relatively short approach channel has concrete approach walls at each end of the spillway. The spillway crest structure has a 560-foot long concrete weir and 13 concrete piers. The weir has an ogee crest at elevation 1180 feet msl, 25 feet above the approach channel floor. Fourteen 40-foot long and 30-foot high tainter gates control flow over the crest. A concrete chute 664 feet wide and 216 feet long connects the weir to the stilling basin. The stilling basin has two rows of baffles, each 12 feet wide and 8 feet high. A stepped end sill provides a transition between the stilling basin floor and the upstream end of the discharge channel. Gavins Point has no outlet works, and all releases in excess of powerplant capacity are made through the spillway. The spillway can discharge 345,000 cfs at a maximum operating pool of 1210 feet msl.

4-04.6.3. **Gavins Point Powerplant.** A curved approach channel guides flows a relatively short distance to the powerhouse intake. Concrete abutment walls are located at each side of the intake. The intake structure has three separate intakes for each of the three power units. Five welded steel trash rack sections are provided at each intake opening. Emergency and service gate slots are provided at each passage. Nine tractor-type, vertical-lift service gates operate in the downstream gate slots. The powerhouse, containing the main structure and the service bay, is integrally constructed with the intake. Three vertical-shaft, single–runner, adjustable-blade Kaplan-type hydraulic turbines with concrete semi-spiral cases and concrete elbow-type draft tubes are installed in the powerhouse. Powerplant discharge capacity is 36,000 cfs at 48 feet of rated head. The generators were rewound from 1987 through 1989 and have a nameplate capacity of 44.1 MW. The tailrace channel conveys flow from the draft tube outlets to the spillway discharge channel. A concrete slab extends 99 feet downstream from the draft tube outlets. The transformer yard is located outside the powerhouse adjacent to the erection bay. The switchyard is located above and south of the transformer yard and contains transformer switching bays, a bus tie bay, and four outgoing line bays.

4-04.6.4. **Gavins Point Water Supply Facilities.** There are no water supply facilities provided from the Gavins Point powerhouse.

4-05. **Missouri River Channel and Floodway Characteristics.** The System, intervening river reaches and lower river reaches extend from Fort Peck in eastern Montana downstream to the confluence with the Mississippi River at St. Louis, as shown on Plate III-1. Plate IV-1 presents the usual time of travel of within-bank, open-water flows for the Missouri River and its major tributaries. It should be noted that these are general approximations that may be affected by many factors. For purposes of scheduling System releases, approximate open water travel times from Gavins Point Dam are 1.5 days to Sioux City, 3 days to Omaha, 3.5 days to Nebraska City, 5.5 days to Kansas City, and 10 days to the mouth of the Missouri River.

4-05.1. The maximum flow that may be passed through a specific river reach without damage, or the channel capacity, varies throughout the length of the Missouri River and is dependent upon channel dimensions, the degree of encroachment upon the floodplain, and improvements such as levees and channel modifications. Channel capacities at specific locations also vary from season to season, especially in the middle and upper reaches. In these two reaches, a decrease in channel capacity due to the formation of an ice cover is common through the winter and early spring months. Generally, the capacity of the Missouri River channel usually increases progressively downstream, although instances do occur where this trend is reversed. Between and below the System dams are reaches of the Missouri River that range in length from 811 miles for the lower Missouri River below Gavins Point Dam to 0 miles between Big Bend Dam and Lake Francis Case. Descriptions of each of these reaches follow.

4-05.2. **Missouri River Reach - Fort Peck Dam to Lake Sakakawea.** The Missouri River from Fort Peck Dam flows in an easterly direction for about 204 miles in an unchannelized river before entering the headwaters of Lake Sakakawea near Williston, North Dakota. Major tributaries include the Milk, Poplar, and Yellowstone Rivers. The Yellowstone River enters the Missouri River just upstream of the Lake Sakakawea delta and influences only a short segment of the Fort Peck reach.

4-05.2.1. Channel characteristics of this river reach include many sandbars, islands, and side channels. Abandoned channels and several oxbow lakes remain in the floodplain. Upstream of Brockton, Montana (RM 1660), the floodplain is about 4 miles wide and is bordered by rolling grasslands, dry-land crops, and rangelands. Downstream from this point, the floodplain narrows to a 1-mile-wide valley surrounded by badlands. Most of the floodplain consists of croplands, pastures, and hayfields in private ownership or in the Fort Peck Reservation. The total reach contains 100,600 acres of agricultural land subject to flooding.

4-05.2.2. **Damage Levels.** Flood damages begin with open water flows of 30,000 cfs. For flows ranging from 50,000 cfs in the upper portion to 70,000 cfs in the lower portion of the reach, damages are relatively minor and limited mainly to pasture and other unimproved lands. Historical regulation has shown that stages at Wolf Point and Culbertson up to 11 feet and 13 feet, respectively, do not cause significant flood damages. During the winter season, the ice-covered channel capacity through this Missouri River reach is limited to 10,000 cfs at the time of ice formation, increasing to over 15,000 cfs after the ice cover has stabilized.

4-05.2.3. **Channel Degradation.** Since the closure of Fort Peck Dam on June 24,1937 most of the channel degradation occurred from date of closure through 1966. Since that time, some degradation has continued in the upper and center portions of the reach. Degradation below the dam (RM 1771.5) occurs at differing rates downstream to about RM 1650. Below RM 1650, no significant degradation has occurred since 1966.

4-05.2.4. **Channel Width.** There has been very little increased channel width due to streambank erosion, except in isolated stretches between RM 1612 and RM 1746. Streambank erosion rates for the 204-mile reach averaged about 97 acres per year from 1975 to 1983. Sediment is being deposited beginning at the mouth of the Yellowstone River and ending in Lake Sakakawea, where a delta has formed because of a reduction in flood flows and the backwater effect of Lake Sakakawea. The associated increase in the elevation of the Missouri and Yellowstone River channels in this area has led to higher river water levels, localized flooding, and higher water tables.

4-05.3. **Missouri River Reach - Garrison Dam to Oahe.** Below Garrison Dam, the Missouri River flows 87 miles in a south-southeasterly direction, passing the cities of Bismarck and Mandan, North Dakota before entering Lake Oahe. Significant tributaries include the Knife

River near Stanton, North Dakota, and the Heart River just upstream of the Lake Oahe delta and downstream of Mandan.

4-05.3.1. **Channel Characteristics.** Within the Missouri River floodplain in the Garrison Dam to Oahe reach, terraces form a complex of different low-lying landforms, many at an elevation within 3 feet above the river. The river is restricted to one main channel in this reach with very few side channels, old channels, or oxbow lakes. The floodplain in this reach contains 34,600 acres of agricultural land subject to flooding. Main damage centers in this reach are the cities of Bismarck and Mandan. Historical regulation has shown that limiting stages at Bismarck to 13 feet does not result in significant flood damages. At the time Garrison Dam was constructed, a 13-foot stage at Bismarck represented an open water channel capacity of about 90,000 cfs; however, in 1997 after 42 years of reservoir operation, the channel had deteriorated to the extent that open water flows of about 50,000 cfs resulted in a stage of 13 feet. During 1997, releases of 59,000 cfs were made from Garrison Dam, resulting in a stage at Bismarck of 14 feet. Some erosion and minor flood damage from water ponding in the yards of homes occurred as a result of this release. A substantial amount of floodplain development at low levels has occurred in the Bismarck and Mandan metropolitan areas. Recent winter operational experience has shown that flows of 20,000 cfs during ice formation and over 28,000 cfs once the ice-cover stabilizes result in a Bismarck stage near 13 feet. This is a reduction from the original Garrison powerplant capacity of 35,000 cfs due to aggradation in the upper end of Lake Oahe.

4-05.3.2. **Channel Degradation.** Degradation of the riverbed below Garrison Dam (RM 1390) occurs primarily in the initial 35-mile stretch below the dam. Channel degradation was greatest before the beginning of power generation in 1956 and began to level off in about 1983. The channel below the dam degraded about 5 feet between 1950 and 1975. Further significant degradation is unlikely to occur, except during high-flow periods. Channel bed grain size has increased over the years in the 25 miles below Garrison Dam, indicating a gradual armoring of the channel bed. The riverbed 25 to 50 miles below the dam continues to degrade, but the rate of degradation became slower after 1975. Since 1960, erosion of the streambed in this part of the reach totals about 4 feet.

4-05.3.3. **Channel Width.** The channel widths for the initial 20 miles below Garrison Dam have remained fairly constant. Only near the mouth of the Knife River (RM 1378) is the channel width decreasing. This decrease is due to a buildup of Knife River deposits resulting from a reduction in flood flow currents. Farther downstream, the channel is widening. Streambank erosion rates were 48 acres per year from 1978 to 1982 for the 87-mile reach and have declined steadily since.

4-05.3.4. **Bank Erosion.** Bank erosion continues in the reach, however, the rate of bank erosion has declined since dam closure in 1953. This is likely due to the reduction in high spring and early summer flows. Before 1953, bank erosion averaged 200 to 250 acres per year. Since 1953, the loss has been about 60 acres per year. A study of the rates of erosion during the 1990's showed the rates to be highly variable, ranging from 35.1 to 86.5 acres per year. The Corps constructed some bank protection in this reach in the 1980's, which has successfully limited the erosion in most sub reaches.

4-05.3.5. **Damage Levels**. This reach has 34,500 acres of cropland subjected to flood damage. The Missouri River area most subject to flooding in this reach, however, is the urban area near Bismarck. Expensive homes constructed in the bottomlands located along the Missouri River are subject to flooding during the winter freeze-in period as well as during significant System inflow events that require releases greater than 60,000 cfs from Garrison Dam. The floodplain construction in the Bismarck area during the past 25 years represents an area of considerable concern that has become more susceptible to future flood control storage evacuation. Damage in this reach will be very high when higher project releases, that are required to evacuate flood storage, occur. Also, this area of Bismarck is subject to potential damage if an ice jam occurs just downstream that backs water into these housing developments. The 2-day water travel time from Garrison Dam to this vicinity prevents any significant control by Garrison Dam during ice jam events.

4-05.4. **Missouri River Reach - Oahe Dam to Lake Sharpe.** This short reach extends from Oahe Dam (RM 1072) five miles downstream to Lake Sharpe (RM 1067), near the city of Pierre, South Dakota.

4-05.4.1. **Channel Characteristics**. This reach is relatively straight, confined to one channel, and dam with no large tributary flows dominating the reach. The Bad River enters near the downstream end of this reach. A large amount of sediment enters the river from this tributary. An EPA-funded Section 319 project in the Bad River basin has reduced this sediment load in recent years.

4-05.4.2. **Damage Levels.** Flooding in the Pierre-Fort Pierre area, especially at street intersections in the Stoeser Addition of Pierre, has been a recurring problem since 1979. Prior to the installation of an emergency gate, high Oahe Dam releases, coupled with the formation of river ice in the LaFrambois Island area, caused water to back up into a storm sewer outlet, flooding street intersections. Public Law 105-277, as amended by Public Law 106-224, authorized and funded for the Fort Pierre and Pierre areas, the design and modification of infrastructure changes, acquisition of the most flood-prone properties, and flood-proofing of other properties. When this project is completed, the Corps anticipates that the Oahe powerplant capacity will continue to be limited but to a lesser extent during the cold winter periods. Release restrictions have been implemented in previous years to prevent flooding. Peak hourly releases, as well as daily energy generation, will be constrained to prevent urban flooding in the Pierre and Fort Pierre areas if severe ice problems develop downstream of Oahe Dam. This potential reduction has been coordinated with the Western Area Power Administration (Western). The urban areas of Pierre and Fort Pierre are subject to high potential damages high if extremely high releases are required from Oahe Dam for flood storage evacuation.

4-05.5. **Missouri River Reach - Fort Randall Dam to Lewis and Clark Lake.** The Missouri River below Fort Randall Dam (RM 880) flows in a southeasterly direction for approximately 44 miles in an unchannelized river to Lewis and Clark Lake. The major tributary in this reach is the Niobrara River, a right bank tributary that enters the Missouri River at RM 843.5. In this reach, the Missouri River meanders in a wide channel with the flow restricted to generally one main channel. Only a few side channels and backwaters are present, except at the lower end of the reach in the Lewis and Clark Lake delta. The 39-mile reach of Missouri River from Fort Randall Dam (RM 880) to Running Water, South Dakota has been designated a National Recreational River under the National Wild and Scenic Rivers Act.

4-05.5.1. **Channel Characteristics.** The tailwater area of Fort Randall Dam, from RM 880 to 860, has experienced up to 6 feet of riverbed degradation and channel widening from 1953 to 1997. The rate of erosion has decreased over this period. Streambank erosion since closure of the dam in 1953 has averaged about 35 acres per year. This compares to a pre-dam rate of 135 acres per year. The Missouri River has coarser bed material above RM 870 than below, indicating some armoring of the channel below the dam. Downstream from the tailwater area, less erosion of the bed and streambank occurs.

4-05.5.2. **Damage Levels.** Since Gavins Point reservoir first filled, a delta has formed at the mouth of the Niobrara River (RM 843.5) to near Springfield, South Dakota. This delta formation has restricted reservoir access at Springfield and caused problems for the city's water intake. While this reach of the Missouri River was capable of passing flows in excess of 150,000 cfs prior to construction of the System, Fort Randall open water releases of 35,000 cfs now result in flood problems. High releases, coupled with diminished channel capacity, caused lowland flooding in this reach during the period from 1995 to 1997. The resulting swampy wetland conditions were very beneficial to migratory waterfowl and other wetland habitat users. In addition, the record high releases in 1997 caused a notable, although as of yet unquantified, increase in the channel capacity in this reach of the Missouri River. It appears quite probable that the channel capacity in the reach has been reduced since 1997. The reach contains approximately 2,200 acres of agricultural land and 62 residential buildings subject to flooding. Corn and soybeans are the primary crops grown. With the severely restricted channel capacity in this reach, inundation of some of the bottomlands adjacent to the channel will likely be necessary in most years that above-normal System inflows must be evacuated.

4-05.6. **Missouri River Reach - Gavins Point Dam to Sioux City.** The Missouri River between Gavins Point Dam (RM 811.1) and Sioux City (732.3) flows in an east-southeasterly direction and is comprised of three sub reaches, the Missouri River National Recreational River, Kensler's Bend, and Missouri River Navigation Channel reaches.

4-05.6.1. **Missouri River National Recreation River Reach.** The 59-mile reach of river downstream of Gavins Point Dam starting at RM 811 down to Ponca, Nebraska (RM 752) is designated as a Missouri River National Recreational River. The National Recreational River reach below Gavins Point Dam has not been channelized by the construction of dikes and revetments. This portion of the river is a meandering channel with many chutes, backwater marshes, sandbars, islands, and variable current velocities. Snags and deep pools are also common. Although this portion of the river includes some bank stabilization structures, the river remains fairly wide. Bank erosion rates since closure of Gavins Point Dam in 1956 have averaged 132 acres per year between Gavins Point and Ponca State Park, compared to a pre-dam rate of 202 acres per year. The rate of erosion had been declining since 1975 and then dramatically increased during the high flow years of 1995 through 1997.

4-05.6.2. **Kensler's Bend Reach.** The Kensler's Bend reach extends from Ponca, Nebraska (RM 752) to above Sioux City, Iowa, (RM 735). The Missouri River banks have been stabilized with dikes and revetments under the Kensler's Bend Project.

4-05.6.3. **Missouri River Navigation Channel Reach.** The reach from the downstream end of the Kensler's Bend Project (RM 735) to Sioux City (RM 732.3) is part of the Missouri River Navigation and Bank Stabilization Project. The channelized reach extends to the mouth of the Missouri River near St. Louis, Missouri.

4-05.6.4. **Channel Characteristics.** The tributaries in the Gavins Point to Sioux City reach are the James River (RM 800.8), Vermillion River (RM 772), and Big Sioux River (RM 734). All are left bank tributaries. Prior to construction of the System, the open water channel capacity through this reach of the Missouri River was well in excess of 100,000 cfs. There is evidence of channel deterioration due largely to floodplain encroachment in backwater areas and along old river meander chutes. This is offset by channel degradation. Extensive bed degradation has occurred in this Missouri River reach because river sediment is captured above Gavins Point Dam. Another factor is the substantial Missouri River channel shortening that occurred as part of the downstream Missouri River Bank Stabilization and Navigation Project. Gradual armoring of the riverbed has reduced the rate of channel degradation. Since 1965, approximately 10 feet of stage reduction has occurred for a discharge of 30,000 cfs.

4-05.6.5. **Damage Levels.** The regulation of the System provides a great amount of flood protection to this Missouri River reach because of the close proximity of this reach to the downstream end of the System. In 1997, flows of 70,000 cfs in this reach caused no significant damage because of the channel degradation that has occurred in this reach. The maximum flow with a stabilized ice cover at which there would be no flood damage is believed to be near 30,000 cfs. The reach contains approximately 1,900 acres of agricultural land and approximately 4,000 residential and nonresidential buildings subject to flooding.

4-05.7. **Missouri River Reach - Sioux City, Iowa to Omaha.** The approximately 116-mile reach between Sioux City (RM 732.3) and Omaha, Nebraska (RM 615.9) is part of the upper Missouri River Navigation and Bank Stabilization Project. Major tributaries in this reach include the Floyd River (RM 731.1) and the Little Sioux River (RM 669.2).

4-05.7.1. **Channel Characteristics.** The Missouri River flows in a south-southeasterly direction through this channelized reach. Open water channel capacities in this reach prior to construction of the System were in excess of 100,000 cfs. During recent years, there has been considerable encroachment on the channel area. Fixed boat docks have been constructed in numerous locations through this reach and low areas are now being cropped. Much of this development is on or adjacent to river stabilization structures and takes advantage of sand deposition encouraged by this stabilization. The extensive degradation (about 10 feet since 1965) noted previously at Sioux City is non-existent at Omaha.

4-05.7.2. **Damage Levels.** Flows of 65,000 cfs in 1975 and 70,000 cfs in 1997 resulted in inundation of some of the cropped land and interrupted access to some marinas constructed along the banks. Some agricultural lands experience interior drainage problems at the higher flow levels as well. Winter flows of up to 30,000 cfs with a stable ice-cover appear possible without flooding. During river freeze-in and ice break-up periods, which can occur at any time during the winter season, flows in excess of 25,000 cfs could result in lowland inundation. Based on the 1996 land survey, the reach contains about 415,000 acres of agricultural land and about 18,500 residential and non-residential buildings subject to flooding**.**

4-05.8. **Missouri River Reach - Omaha to Kansas City.** The Missouri River reach from Omaha (RM 615.9) to Kansas City, Missouri (RM 366.1) flows in a south-southeasterly direction for approximately 250 miles. Major tributaries in this reach include the Platte River (RM 494.8), Nishnabotna River (RM 542), and Kansas River (RM 367.5). Deterioration of the channel and flood capacity has occurred throughout this reach. Recent experience indicates that mid-summer flows exceeding 90,000 cfs will result in river levels above flood stage at Nebraska City, Rulo, and St. Joseph. Complaints are received from adjacent landowners concerning water logging of cultivated fields with stages at 2 feet below flood stage. During the winter months, stages in this reach have gone as much as 5 feet above flood stage due to ice jams even though Gavins Point Dam releases were limited to 20,000 cfs and there was little incremental inflow occurring below Gavins Point Dam. This reach contains about 360,000 acres of agricultural land and about 2,650 residential and commercial buildings subject to flooding.

4-05.9. **Missouri River Reach - Kansas City to Mouth of Missouri River.** From Kansas City (RM 366.1), the Missouri River flows 366 miles in an easterly direction to its confluence with the Mississippi River (RM 0). Major tributaries in this reach include the Grand (RM 250), Chariton (RM 238.9), Osage (RM 130), and Gasconade (RM 104.5) Rivers. Open-water flows of about 150,000 cfs will cause only relatively minor agricultural damages in this reach. In the vicinity of Kansas City, the channel is experiencing both a deterioration of the flood conveyance capacity in the overbank area and, simultaneously, increased channel capacity through channel degradation. This channel degradation has adversely impacted water intakes in this reach during low winter stages. In recent years, the established flood stage on the Missouri River at Waverly, Missouri, has been exceeded when flows were greater than 115,000 cfs. This lowest reach of the Missouri River has historically experienced a deterioration of the flood conveyance capacity. The reach contains about 472,000 acres of agricultural land and about 4,800 residential and commercial buildings subject to flooding. Ice jams can cause flooding with flows of less than 30,000 cfs on this reach of the Missouri River.

4-05.10. **System Flood Damage Levels.** The three primary resources directly affected by the System’s ability to control floods are agricultural resources, nonagricultural resources and navigation.

4-05.10.1. **Agricultural Resources.** Approximately 1.4 million acres of agricultural land is subject to flooding along the Missouri River. Ninety percent of these acres are located downstream of Gavins Point Dam. Corn is the primary crop cultivated, followed by soybeans and wheat. In total, approximately 42,800 acres of Tribal lands are also subject to flooding. Most of the Tribal lands are on the Fort Peck Reservation. Grassland is not included in the above acreage figures.

4-05.10.2. **Nonagricultural Resources.** Nonagricultural resources include residential and nonresidential structures located in areas along the Missouri River that are subject to flooding. There are 30,395 residential buildings worth approximately $1.9 billion located within identified flood hazard areas. There are 5,345 nonresidential buildings subject to flooding, with a total value of approximately $15.7 billion (Corps, 1998e). Residential development is characterized according to 10 general classes of residential buildings. Farmsteads are included in the residential building category. For nonresidential structures, over 100 building categories were used for the initial classification. The value of each structure is based upon the size, condition, and construction type and includes the value of the building's contents. This development has been growing much faster in recent years than in the past as the floodplain is being developed and expensive structures are being constructed. Development on Tribal lands adjacent to the Missouri River floodplain includes about 475 buildings worth an estimated $62 million. Approximately 96 percent of this estimated value is located on the Fort Peck Reservation.

4-05.11. **Navigation.** Flood flows greater than a 25-year flood event have the potential to adversely affect navigation on the Missouri River. Navigation losses result from interrupted service. The duration of the interruption depends on the length of river affected and the magnitude of the flood. Losses are based on daily barge and towboat costs and the average daily tonnage moved during the month that a flood occurs.

4-05.12. **System Flood Damages Prevented Report.** The RCC provides the Omaha and Kansas City District's planning sections the basic hydrologic data to determine the damages prevented of both actual and without dams (natural) conditions by the System. The districts then apply the hydrologic data using stage-discharge-damage curves for the various reaches of the System. The computed damages prevented are then provided to the RCC and higher authority on an annual basis. The flood control effects of the Missouri River levee system are included in the determination, and the System fair-shares the benefits with the levee system. Fair-sharing occurs unless the levee system would have been overtopped by the natural events. In the case of levee overtopping, the System gets the full credit for damages prevented for the river reach for that flood event. Tributary reservoir effects are accounted for, and if the tributary projects have authorized flood control storage, they receive credit for damages prevented. If they do not have authorized flood control, the benefits are assigned to the System, because on all events to date, the System could have contained the flood runoff without releasing additional damaging flows. The estimated accumulated flood damages prevented by the System is $24.8 billion from 1938 to 2001, or $393.7 million annually.

4-05.13. **System Stage-Discharge-Damage Curves.** Rating and damage curves, relating stages at particular locations with open-river discharges and with damages through an adjacent reach along the Missouri River, are shown on Plates IV-2 through IV-13. Damage curves have been developed for both existing and natural (without levees) conditions. This was done to determine the effect of protective levees that have been built in many reaches of the Missouri River below Sioux City. Levees currently in place provide protection, as indicated by the existing curves. The curves denoted as "natural" indicate the damages that would result at any particular stage with complete levee failure or overtopping through the affected reach.

4-06. **System Related Control Facilities.** The following facilities were designed and do work in concert with the System to provide an improved Missouri River basin water management condition. The following subparagraphs are devoted to describing the projects other than the System that affect, or influence, water management in the Missouri River basin.

4-06.1. **Missouri River Basin - Tributary Reservoirs.** The facilities that have the greatest affect on the System are the tributary reservoirs. A significant number of tributary reservoirs have been constructed in the Missouri River basin, many as a result of the 1944 Flood Control Act and others for general water resource development purposes. The cumulative effect provided by these tributary reservoirs on the System is significant. In 2002, the 529,350-square mile Missouri River basin contained about 3,100 multiple-purpose reservoirs and over 14,100 single-purpose reservoirs, either completed or under construction. In the aggregate, these reservoirs provide a total of over 141 MAF of storage capacity. The investment cost for this storage capacity exceeds $15 billion. Almost 99 percent of the total storage capacity serves multiple-purpose functions. Purposes served by individual multiple-purpose reservoirs may include any combination of the purposes of flood control, municipal and industrial water supply, water quality control, irrigation, navigation, hydroelectric power, fish and wildlife enhancement, and recreation. In contrast, the function of most single-purpose reservoirs is either flood control or water supply. Pertinent data from reservoirs in the basin, including all of the reservoirs in which the Corps has an operational responsibility, are listed in Table IV-1and IV-2. Locations of the major reservoirs, as well as the locations of other water resource developments discussed subsequently herein, are shown on Plate III-23. The tributary reservoirs are divided into two groups for purposes of discussion; those above the System are called Upstream Tributary Reservoirs and those below the System are called Downstream Tributary Reservoirs.

4-06.1.1. **Missouri River Basin – Upstream Tributary Reservoirs.** Although it is relatively simple to approximate the effects of a single tributary reservoir upon specific streamflow occurrences, provided flow and storage data are available, such a process becomes exceedingly complex with the large number of such reservoirs existing in the Missouri River basin. The approximation process becomes further complicated with recognition of the many small projects in existence for which no hydrologic data are available. Individually, these small projects have insignificant effects on Missouri River flows; however, when considered in the aggregate, this effect may be very significant. Certain general conclusions, as given below, may be deduced relative to the effect on streamflow of these projects. Many of these projects are not regulated specifically for flood control; however, their releases are integral to total System regulation.

4-06.1.1.1. On an annual or other long-term basis, the existence of tributary reservoir storage will result in a decrease in Missouri River streamflow. In addition to the consumptive use of water from the projects, nearly all are located in regions where the volume of evaporation from the reservoir will exceed the volume of precipitation that may fall directly on the pool. During any flood season, the existence of upstream tributary storage will almost certainly reduce System flood volumes to some extent, the amount being dependent on antecedent conditions. Although specific flood control storage may not be allocated, these reservoirs are located in regions where flows are of a distinct seasonal nature. Reservoir regulation to achieve the purposes that the reservoirs serve results in storing water during periods of excess flows. The stored water is then used later during periods of low runoff. This stored water will reduce flood volumes and peak inflows into the System and augment the amount of water in System storage during low-inflow periods into the System later in the season.

4-06.1.1.2. Normally, the natural crest flows on the Missouri River will also be reduced by the existence of tributary reservoir storage, provided significant runoff contributing to the crest flow originates above the tributary projects. Reasons for this are discussed in the preceding paragraphs, plus the additional effects of the tributary reservoirs in smoothing and delaying sharp crests even if there were no appreciable vacant storage space remaining at the time of the crest. It is realized that, in certain instances, a reservoir project can increase the size of the crest below the project over that which would have occurred naturally. This is due to the reservoir decreasing the travel time of the crest flow or by delaying a portion of the runoff from a sub-area that is later contributing to a major upstream crest on the Missouri River when releases from the tributary reservoir are made. With a single tributary reservoir, or only a few projects, such an increase in crests flows might occasionally be expected. With the large number of projects tributary to the Missouri River, it is not likely that their aggregate effect would increase Missouri River crest flows.

4-06.1.1.3. The Corps of Engineers is responsible for flood control regulation of all Federal reservoirs with allocated flood control space. Many of these reservoirs will be regulated, insofar as practical, to prevent local flood damages along both the tributary streams and on the Missouri River downstream from the reservoirs. Regulation of the tributary reservoirs will be coordinated with regulation of the System at times of large flood flows or large quantities of water in System storage. Table IV-1 provides pertinent data of larger reservoirs above Gavins Point Dam. One reservoir, Canyon Ferry is located on the Missouri River above the System while all others are tributary reservoirs regulated by either the Corps or USBR.

4-06.1.2. **Missouri River Basin – Downstream Tributary Reservoirs.** There are no reservoirs located on the main stem of the Missouri River below the System. Many tributary reservoirs provide some control of the flows to the Missouri River and, at times, have a significant effect on Missouri River levels and regulation of the System. Chapter VII provides some insight on how the lower basin tributary reservoirs effect System regulation. One difference is that three reservoir projects located downstream of the System are used at times to support navigation on the Missouri River. These three reservoir projects are located in the Kansas River basin: the Milford, Tuttle Creek, and Perry projects. Table IV-2 provides a list of the larger tributary reservoirs located below the System.

4-06.2. **Missouri River Basin – Upstream Tributary Levee Projects.** In addition to levee protection along the Missouri River, the comprehensive plan for basin development included many protection projects for localities in the upstream reaches of the Missouri River or on tributary streams. Some of the projects are designed to provide protection in combination with flood control reservoirs constructed upstream from the affected locality. Description of each of these projects is beyond the scope of this manual, and reference is made to individual System project water control manuals or tributary reservoir water control manuals for descriptions of these projects.

4-06.3. **Missouri River Basin - Downstream Levee Structures.** The drainage area above Gavins Point Dam is 279,480 square miles, 52 percent of the basin total of 529,350 square miles. The ability to control the movement of water in the lower Missouri River decreases the farther downstream from Gavins Point Dam a particular location is. Sioux City has 88 percent of the drainage area controlled by the System while Omaha has 86 percent. Values continue to drop to 68, 66, 57, 55, and 53 percent for Nebraska City, St. Joseph, Kansas City, Boonville, and Hermann, respectively. The production of food is the major industry in the large agricultural region that makes up the Missouri River basin. More than 1.5 million acres of the most productive farm land within the basin, the associated livestock, equipment, farm buildings, and other improvements, and numerous rural communities are located on the floodplain of the Missouri River between Sioux City and the river's mouth.

4-06.3.1. **Missouri River Basin – Downstream Federal Agricultural Levee Projects**. Federal levee construction in accordance with the 1941 and 1944 Flood Control Acts was started in 1947. The levees are designed to function as a team with System and tributary reservoirs. Neither the reservoirs alone nor the levees alone provide the desired degree of protection, but operating to supplement each other, they provide protection against floods equal to any of past record. The whole system of Federal levees is constructed in individual units. Older levees were built of semi-compacted earth fill with a top width of 10 feet, side slopes of 1 on 3, and a freeboard of 2 to 3 feet above the water surface of the design flood. New construction of the levees remains similar, but the design is based on risk analysis at a 90 percent confidence level. Landside berms or seepage wells are provided where foundation conditions require such measures. Drainage structures extend through the levees to provide adequate internal drainage.

4-06.3.2. At the end of 2001, 29 Federal units were either constructed or under construction. With the exception of two units between Kansas City and Boonville, Missouri, all Federal levees now constructed are in the reach located between Omaha and Kansas City. While additional units appear economically feasible, they presently are in an inactive status. Design discharges of these Federal levees range from 250,000 cfs at Omaha, 295,000 cfs at Nebraska City, 325,000 cfs at St. Joseph, 425,000 cfs at Kansas City, and up to 620,000 cfs at Hermann, Missouri, near the mouth of the Missouri River. Detailed locations of these levees and their protected areas, are shown in the Project Maps, as published and revised annually by the Corps' Omaha and Kansas City District offices.

4-06.3.3. **Missouri River Basin - Downstream Federal Urban Levee Projects**. Levee projects for the protection of large urban areas along the Missouri River have been constructed at Omaha; Council Bluffs, Iowa; and Kansas City. The Kansas City project was authorized by the 1936 Flood Control Act and modified and extended by the Acts of 1944 and 1954. The authorizations for the Omaha and Council Bluffs projects were included in the 1944 Flood Control Act. These projects are designed to operate in conjunction with the System and tributary reservoirs to prevent flooding of these localities from the most severe flood events of record. Design discharge of the Omaha-Council Bluffs project is 250,000 cfs, while levees in the Kansas City area are designed for Missouri River flows of 540,000 cfs. In addition to the large projects, a short levee constructed by the Corps under Section 212 protects the town of New Haven, Missouri from Missouri River floods.

Table IV-1
Large Reservoir Projects in the Upper Missouri River Basin– Pertinent Data

Project Name	Location (City, State)	Drainage Area (sq. mi).	Regulated By
Gavins Point Dam	Yankton, SD	16,000	Corps
Fort Randall Dam	Pickstown, SD	14,150	Corps
Big Bend Dam	Fort Thompson, SD	5,840	Corps
Oahe Dam	Pierre, SD	62,090	Corps
Garrison Dam	Riverdale, ND	123,900	Corps
Fort Peck Dam	Fort Peck, MT	57,500	Corps
Clark Canyon (1)	Dillon, MT	2,320	USBR
Canyon Ferry (1)	Helena, MT	13,580	USBR
Gibson	Augusta, MT	575	USBR
Tiber (1)	Chester, MT	4,920	USBR
Fresno	Havre, MT	3,776	USBR
Bull Hook	Havre, MT	54	Corps
Buffalo Bill	Cody, WY	1,500	USBR
Boysen (1)	Thermopolis, WY	7,710	USBR
Yellowtail (1)	St. Xavier, MT	10,420	USBR
Dickinson	Dickinson, ND	400	USBR
Heart Butte (1)	Glen Ullin, ND	3,400	USBR
Bowman Haley	Scranton, ND	446	Corps
Shadehill (1)	Lemmon, SD	3,070	USBR
Keyhole (1)	Moorcroft, WY	1950	USBR
Belle Fourche	Belle Fourche, SD	205	USBR
Deerfield	Rapid City, SD	95	USBR
Pactola (1)	Rapid City, SD	214	USBR
Coldbrook	Hot Springs, SD	71	Corps
Cottonwood Springs	Hot Springs, SD	26	Corps
Angostura	Hot Springs, SD	9,100	USBR

(1) USBR Section 7 project

Table IV-2
Reservoir Projects Located in the Lower Missouri River Basin

Project Name	Location (City, State)	Drainage Area (Sq. Mi.)	Regulated By
Milford Lake	Junction City, KS	3,620	Corps
Wilson Reservoir	Russell, KS	1,917	Corps
Glen Elder Dam (1)	Beloit, KS	5,076	USBR
Kirwin Dam (1)	Kirwin, KS	1,409	USBR
Webster Dam (1)	Stockton, KS	1,150	USBR
Cedar Bluff Dam (1)	Ellis, KS	5,365	USBR
Bonny Dam (1)	Hale, CO	1,435	USBR
Enders Dam (1)	Imperial, NE	951	USBR
Trenton Dam (1)	Trenton, NE	8,624	USBR
Kanopolis Reservoir	Lindsborg, KS	2,330	Corps
Tuttle Creek Reservoir	Manhattan, KS	9,556	Corps
Harlan County Dam	Republican City, NE	20,751	Corps
Medicine Creek Dam (1)	Cambridge, NE	642	USBR
Perry Reservoir	Topeka, KS	1,117	Corps
Clinton Reservoir	Lawrence, KS	367	Corps
Smithville Reservoir	Platte City, MO	213	Corps
Longview Lake	Lee's Summit, MO	50.3	Corps
Blue Springs Lake	Lee's Summit, MO	32.8	Corps
Pomona Reservoir	Osage City, MO	322	Corps
Melvern Reservoir	Osage City, MO	349	Corps
Hillsdale Lake	Paola, KS	144	Corps
Stockton Lake	Stockton, MO	1,160	Corps
Pomme De Terre Lake	Hermitage, MO	611	Corps
Harry S Truman Reservoir	Warsaw, MO	11,500	Corps
Lake of the Ozarks	Lake Ozark, MO		Non Federal
Lovewell (1)	Lovewell, KS	358	USBR
Longbranch Lake	Macon, MO	109	Corps
Rathbun Lake	Rathbun, IA	549	Corps
Red Willow Dam (1)	McCook, NE	310	USBR
Norton (1)	Norton, KS	688	USBR
Jamestown Dam (1)	Jamestown, ND	1,300	USBR
Pipestem Dam	Jamestown, ND	400	Corps
Chatfield Dam	Denver, CO	3,018	Corps
Bear Creek Dam	Denver, CO	261	Corps
Cherry Creek Dam	Denver, CO	386	Corps
Glendo Dam (1)	Glendo, WY	14,330	USBR
Pathfinder Dam	Alcova, WY	14,600	USBR
Seminoe Reservoir	Sinclair, WY	7,210	USBR

(1) USBR Section 7 project

4-06.3.4. **Missouri River Basin - Downstream Private Levee Projects.** In addition, railroads, highways, bridges, and municipal developments within the floodplain increase the necessity for adequate flood protection in the non-urban Missouri River bottom areas. Local interests have built many miles of levees, comprising over 500 non-Federal levee units through this reach of the river. These are listed in appropriate Flood Emergency Plans; however, most of these levees are inadequate to withstand major floods. Still, they provide protection during the majority of events.

4-06.4. **Missouri River Basin – Missouri River Streambank Stabilization.** The following paragraphs discuss the programs implemented to stabilize the banks of the Missouri River. Streambank erosion is a continuing problem along most of the main stem and many tributaries in the Missouri River basin. Most bank protection projects now in existence are comparatively small and many have been of an emergency nature. This is particularly true for tributary streams and the upper two-thirds of the Missouri River. Numerous bank protection projects have been installed below the Garrison, Fort Randall, and Gavins Point Dams and additional revetments will probably be required in future years below all of the projects due to increased river front development. These projects are very small compared to the most significant bank-erosion control achievements in the basin, the Missouri River Navigation and Bank Stabilization Project from Sioux City, Iowa (RM 735) to the mouth and the Kensler's Bend Project between Ponca State Park, Nebraska (RM 753) and Sioux City. Prior to stabilization, the Missouri River banks were subject to serious erosion. Development along the Missouri River was very limited because of this bank erosion in combination with serious flooding. Prior to System regulation, high bank erosion and high bank accretions would be comparable over time; however, since the reservoirs act as a sediment trap, this is no longer the case. In the Missouri River below the System, the flow of the river during moderate and low flow periods is confined to one designed alignment, stabilized by permanent rock dikes and bank revetments. Although some natural side channels exist and some historic side channels have been recently restored to provide fish and wildlife habitat, the lower one-third of the main stem of the Missouri River remains highly channelized.

4-06.4.1. **Missouri River Basin – Upstream Bank Stabilization**. There are numerous bank stabilization projects located in and above the System that provide bank stabilization along the Missouri River and its tributaries. These projects are not addressed in detail in this Master Manual but the larger projects are discussed in the individual System projects' and tributary projects' water control manuals.

4-06.4.2. **Missouri River Basin – Downstream Bank Stabilization.** This reach of the river has been modified over its entire length by an intricate system of dikes and revetments designed to provide a continuous navigation channel without the use of locks and dams. Authorized channel dimensions are achieved through supplementary releases from the large upstream reservoirs and occasional dredging and maintenance. In addition, when certain conditions warrant, supplemental flows are provided from specific tributary reservoirs to support Missouri River navigation to conserve System storage. The Missouri River reach from Gavins Point Dam to St. Louis includes numerous authorized projects that provide bank stabilization and a navigation channel. In addition to the primary authorization to maintain a 9-foot deep by 300-foot wide navigation channel from Sioux City to the mouth, there are authorizations to stabilize the riverbanks. This project is referred to as the Missouri River Bank Stabilization and Navigation project and extends from just above Sioux City to the mouth of the Missouri River, a distance of 735 river miles.

4-06.4. 2.1. The Missouri River Bank Stabilization and Navigation Project (BSNP) was designed to prevent bank erosion and channel meandering and to provide reliable Missouri River navigation. This project, authorized by Congress in the Rivers and Harbors Act of 1945, provides for a 9-foot deep channel with a minimum width of 300 feet from near Sioux City to the mouth of the river near St. Louis, a distance of 735 miles. Construction of the navigation works was declared complete in September 1981, although corrective work will be required as the Missouri River continues to form its channel in response to changing flow conditions. The navigation project is not accomplished by using locks, as is the case on most of the inland waterway systems, but by using river structures placed to confine and control the channel. The use of these structures produces velocities high enough to prevent the accumulation of sediment in the channel and permits an open condition for the entire length of the project with no dredging required under normal water supply conditions. The Missouri River, as previous discussed, therefore, has higher velocities than other inland navigation systems that can present challenges in navigating the river.

4-06.4.2.2. Commercial navigation in the Missouri River is confined to the main stem of the Missouri River between Sioux City and the mouth of the Missouri River near St. Louis. The Missouri River Navigation and Stabilization Project, discussed in the preceding paragraph, is designed to secure a permanent, continuous, open-river navigation channel with a 9-foot depth and a width of not less than 300 feet under full navigation service conditions. Maintenance of these dimensions requires releases from the System, as well as some infrequent dredging activities, particularly during periods of sub-normal water supply. This navigation project is an important link with the Mississippi River waterway system. Low-cost transportation, particularly for bulk commodities, is available at many localities in the Missouri River valley. Cities and commercial interests have provided facilities along the banks of the river for both handling and managing navigation traffic.

4-06.4.3. **Bank Stabilization on Tribal Cultural Resource and Archeological Sites.** In addition to the above-mentioned bank stabilization efforts there is an ongoing effort to stabilize portions of the System to protect Tribal cultural resource and archaeological sites. The Corps, through the Corps' Operation and Maintenance appropriations, continues to make progress in Missouri River bank stabilization efforts for the protection of archaeological sites. Table IV-3 details those efforts during the past few years. The Corps consults with American Indian Tribes, Tribal Historic Preservation Offices, and State Historic Preservation Offices to determine priority sites where bank stabilization efforts should be focused. Site-stabilization work is contingent upon available funds. Additional sites will be protected as funding becomes available.

4-06.5. **Missouri River Basin – National Recreational River Designations.** Two sections of the Missouri River have been declared National Recreational River reaches. They are described in the following paragraphs.

4-06.5.1. **Missouri River Basin - National Recreational River.** The 36 miles of river from Fort Randall Dam (RM 880) to the Lewis and Clark Lake delta (RM 844) is designated a National Recreational River under the National Wild and Scenic Rivers Act. The banks along this reach tend to restrict flow to one main channel. There are only a few side channels and backwaters, except at the lower end in the Lewis and Clark Lake delta. The Missouri River bank line that borders the Yankton Reservation is located adjacent to this reach, from RM 880 downstream to RM 845. The Fort Randall reach receives no significant inflow from tributaries other than the Niobrara River.

4-06.5.2. **Missouri River Basin - Downstream National Recreational River.** The 59-mile stretch of river between Gavins Point Dam (RM 811) and Ponca (RM 752) is designated a National Recreational River under the National Wild and Scenic Rivers Act. It is also the only river segment downstream of Gavins Point Dam that has not been channelized by dikes and revetments. A wide, braided channel and numerous islands, chutes, and backwaters favor a variety of wetlands. The Gavins Point reach resembles the original undeveloped Missouri River more than any other reach, and compared to the other reaches, displays the greatest density of wetlands, approximately 90 acres per mile. Wetland acreage, however, has undoubtedly declined in the years following the designation as a result of channel degradation. Major tributaries in the Gavins Point reach are the James and Vermillion Rivers.

4-06.6. **Missouri River Basin - Federal and State Fish Hatcheries.** Two existing Federal fish hatcheries and one fish hatchery currently being constructed are located on or adjacent to System projects. The following paragraphs describe these facilities. Appendix C of the Final Environmental Impact Statement for the water control plan discusses fish propagation activities of both Federal and State fish hatcheries for native and endangered species with regard to the Missouri River and the System. That discussion will not be repeated in this Master Manual.

4-06.6.1. **Fort Peck Dam National Fish Hatchery.** This is a Federal fish hatchery that is currently being constructed adjacent to Fort Peck Dam. When completed, it will be operated as a National Fish Hatchery.

4-06.6.2. **Garrison Dam National Fish Hatchery.** This hatchery was originally established in 1957 to provide fish for recreational fishing in the new reservoirs created by Federal water development projects in the Midwest. The Service operates this hatchery. Today, the hatchery continues to provide management and production of many freshwater fishes for the System, National Wildlife Refuges, American Indian waters, and programs of the State of North Dakota. As many of the native fishes struggle with the changes in the Missouri River aquatic ecosystems, the hatchery's role has changed to include maintaining migratory fishes, such as the paddlefish, and restoring endangered species, such as the pallid sturgeon. To meet the high fish production demands, Garrison Dam National Fish Hatchery encompasses 209 acres of land and has a total of 64 rearing ponds.

Table IV-3
Bank Stabilization Efforts for the Protection of Archaeological Sites

Name	Fiscal Year	Expenditures ($thousands)
Havens	1987	20
Havens	1988	77
Fort Randall Historical Site	1988	24
Whistling Elk	1988	77
Cemetery Relocation	1988	20
Crow Creek	1989	78
Travis 11	1990	25
Fort Rice Dam	1993	7
Forest City/Cheyenne River	1993	23
Stoney Point	1993	6
Fort Rice Dam	1994	20
Old Scout Cemetery (BIA)	1995	48
Iron Shooter	1996	22
South Iron Nation (Vegetative)	1996	68 [a/]
Heavens Arch	1998	50
Fort Yates	1998	118
Rorgo/Walth Bay	1998	74
Stoney Point (con't)	1998	54
Iron Shooter (con't)	1998	45
South Iron Nation (con't)	1998	38
Molstad	1999	51
Vanderbuilt	1999	112
Rorgo/Walth Bay (con't)	1999	2
Fort Yates (con't)	1999	6
Havens Arch	1999	49
South Iron Nation (con't)	1999	111
Stoney Point (con't)	1999	84
Mobridge Village	2000	97
Molstad (con't)	2000	56
Vanderbuilt (con't)	2000	168
South Iron Nation (con't)	2000	222
Leavenworth	2001	310
Jake White Bull	2001	195
Fort Rice	2001	653
Leavenworth (con't)	2002	207
Jake White Bull (con't)	2002	15
Fort Rice (con't)	2002	132
White Swan/St. Philips	2002	24
White Swan/St. Philips (con't)	2003	196
Crow Flies High	2003	607
Nishu Point	2003	104
Protection of Fort Randall Chapel	2003	280
Cattle Oiler	2004	250 [b/]
Short Creek	2004	250 [b/]
North Cannonball	2004	900 [b/]
Terrace Complex	2004	400 [b/]

a/ Estimated value of volunteer service.

b/ Planned expenditures for fiscal year

4-06.6.3. **Gavins Point National Fish Hatchery and Aquarium.** The Gavins Point National Fish Hatchery and Aquarium is located just downstream of Gavins Point Dam on the South Dakota side of the Missouri River. The hatchery that began operations in 1961, raises 12 to 16 species of sport fish, and has produced more than 5 billion fish for stocking or release in Midwestern waters. The hatchery raises the endangered pallid sturgeon and the paddlefish, both of which are native to the Missouri River. The hatchery has 36 rearing ponds that cover 40 acres. The Service also operates this fish hatchery.

4-06.7. **System Public Recreation Facilities.** Recreation at System projects consists of both water-based and land-based activities. Water-based recreation includes boating, fishing, water skiing, jet skiing, and swimming. Land-based recreation includes hunting, camping, picnicking, sightseeing, hiking, and wildlife photography. Visitors participate in these activities at recreation areas that range from undeveloped lake access points to highly developed and extensively used campground areas. The six System projects have a total of 179 public recreation areas. The number of recreation areas by System projects includes 22 at Fort Peck, 35 at Garrison, 51 at Oahe, 24 at Big Bend, 24 at Fort Randall, and 23 at Gavins Point. In 2002, most of the South Dakota Federal recreation areas were transferred in fee title to the State of South Dakota or to the Bureau of Indian Affairs (BIA), which holds the areas in trust for the Lower Brule Sioux Tribe and the Cheyenne River Sioux Tribe, under Title VI of Public Law (P.L.) 105-53, Water Resources Development Act of 1999 as amended by P.L. 106-541, Water Resources Development Act of 2000. The 65 recreation areas transferred in fee title, along with the nine recreation areas leased in perpetuity, will be managed for the restoration of terrestrial wildlife habitat loss that occurred as a result of the flooding of lands related to the construction of the Oahe, Big Bend, Fort Randall, and Gavins Point projects. Table IV-4 presents the Natural Resource Management System reporting area recreation sites, marinas, camping sites and swimming areas for each System project.

Table IV-4
Missouri River System Recreation

Reservoir	NRMS Recreation Areas*	Marinas	Camping Sites	Swimming Areas
Fort Peck Lake	26	3	231	3
Lake Sakakawea	45	9	1,111	4
Lake Oahe	52	4	995	5
Lake Sharpe	31	1	371	7
Lake Francis Case	31	3	578	6
Lewis and Clark Lake	28	2	1,022	7
Total	**213**	**22**	**4,308**	**32**

* The Natural Resource Management System (NRMS) reporting areas include sites where visitor use occurs and may include visitor centers, powerplant exhibit areas, cabin sites, fishing access areas, campgrounds, multiple-use areas, and day-use facilities. These areas are located both upstream and immediately downstream of the dam within the project boundary. The 179 total sites referred to in the above paragraph are just public recreation areas on the respective System projects.

4-06.8. **Missouri River Basin - Irrigation Facilities.** Irrigation is the largest single use of water in the Missouri River basin. As of 1965, about 7.4 million acres of irrigated land, including 6.9 million acres of cropland and 0.5 million acres of pasture, required an annual farm delivery in excess of 14 million acre-feet of water. Of this total, about 5.8 million acres are served by group irrigation systems. These systems have an aggregate reservoir storage capacity of nearly 9 million acre-feet and about 42,000 miles of group-delivery canals. About 45 percent of the storage capacity for group irrigation systems is in reservoirs constructed by irrigation districts, water companies, or the States, with Federal projects accounting for the remainder. About 70 percent of the irrigated area is served by surface water, and about 30 percent is served by groundwater. In years of deficient water supply, a significant portion of the area normally irrigated cannot be furnished the water required.

4-06.8.1. Since 1965, an estimated additional 4 million acres have been placed under irrigation in the Missouri River basin, predominantly from groundwater sources and by private enterprise. Only about one-fifth of the potentially irrigable lands in the basin are irrigated. Consequently, a continuing growth can be expected in the future. Over 6 million additional acres in the basin are estimated to be irrigated eventually. One of the major components of the Pick-Sloan Plan was the Federally funded Oahe (Oahe Diversion) and Garrison (Garrison Diversion) irrigation projects. While the facilities have been constructed to pump this water from Oahe and Garrison System projects, the actual irrigation of lands has not occurred. The Oahe Diversion project has been de-authorized, and the Garrison Diversion project has been significantly scaled back over the past 20 years. No acres are currently irrigated with the Garrison Diversion project.

4-07. **System Real Estate Acquisition.** Construction of the System required the acquisition of approximately 1.7 million acres in fee, public domain transfers, and easements. The individual System projects' Water Control Manuals contain additional details regarding real estate acquisition and relocations for that specific project. The following paragraphs contain a brief description of the acquisitions for the System, the largest reservoir system in the United States.

4-07.1. **Fort Peck Real Estate Acquisition.** Approximately 590,085 acres, with 167,705 acquired in fee and 422,069 from public domain and 311 acres in easement, were acquired for the Fort Peck – Fort Peck Lake System project. Land acquisition was based on a guide-taking line at an elevation of 2250 feet msl (top of the Exclusive Flood Control Zone) from the dam to RM 1863 (approximately 3 miles below the Musselshell River). Land was acquired to a guide-taking line at an elevation of 2270 from RM 1863 to 1932 because of the flatness of the terrain and the problem with winter ice-jam flooding in this reach.

4-07.2. **Garrison Real Estate Acquisition.** Almost one-half million acres of real estate in fee and just less than 3,000 acres in easement were acquired for the Garrison Dam – Lake Sakakawea System project. Land acquisition was based on a guide-taking line at an elevation of 1855 feet msl (1 foot higher than the top of the Exclusive Flood Control Zone) for a major portion of the reservoir area. In the upper end of Lake Sakakawea, the high potential for aggradation and backwater effects was recognized; therefore, land was acquired to an elevation of 1860 feet msl.

4-07.3. **Oahe Real Estate Acquisition.** Over 400,000 acres of real estate in fee and 2,417 acres in easement were acquired for the Oahe Dam – Lake Oahe System project. Land acquisition was based on a guide-taking line at an elevation of 1620 feet msl (top of the Exclusive Flood Control Zone) with allowances for wave heights, set-up, wave run-up, erosion, and bank caving. In the upper end of the Lake Oahe, aggradation and backwater effects were recognized; therefore, land was acquired to an elevation of 1630 feet msl.

4-07.4. **Big Bend Real Estate Acquisition.** Approximately 44,870 acres in fee and 160 acres in easements were acquired for the Big Bend Dam – Lake Sharpe System project. Land acquisition was based on a guide-taking line at an elevation of 1423 (top of the Exclusive Flood Control Zone) with allowances for wave heights, set-up, wave run-up, erosion, and bank caving, or a 300-foot setback from the 1423 feet msl contour, whichever was the greater. Flowage easements were acquired on four tracts of land having a total area of less than 10 acres.

4-07.5. **Fort Randall Real Estate Acquisition.** Approximately 114,163 acres in fee and 649 acres in easements were acquired for the Fort Randall Dam – Lake Francis Case System project, including 514 acres of flowage easements at 15 locations. In addition, Public Land Order transferred 173 acres from the public domain. Of the total originally acquired for Fort Randall, approximately 15,000 acres were later included as necessary real estate for the Big Bend Dam – Lake Sharpe System project. A guide-taking line at an elevation of 1375 feet msl (top of the Exclusive Flood Control Zone) was the basis of the acquisition over most of the reservoir area.

4-07.6. **Gavins Point Real Estate Acquisition.** Approximately 34,474 acres in fee and 212 acres in easements were acquired for the Gavins Point Dam – Lewis and Clark Lake System project. No public domain land was involved at this project. The guide-taking line for the main body of the reservoir was to an elevation of 1210 feet msl (top of the Exclusive Flood Control Zone) with a provision for wave heights, erosion, bank caving, reservoir set-up, and wave run-up. Provision was also made for raising the elevation of the taking line in upper reaches of the reservoir to allow for sedimentation and backwater effects.

V - DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. **Hydrometeorologic Stations.** This section describes the data collection methods and locations to meet the Corps' mission of managing the Nation's water resources in the Missouri River basin.

5-01.1. **Data Collection System.** Effective reservoir regulation of the System requires accurate real-time data relating to existing and anticipated hydrologic and meteorological conditions within the Missouri River basin. Due to the wide seasonal and area1 variations of hydrologic events within this very large basin, it is necessary to integrate a large volume of basic data pertinent to runoff and water supply in order that the System can be regulated to meet the operational objectives for which the System was originally designed. The RCC has created and maintained the Missouri River Automatic Data System (MRADS) since 1978 to serve that purpose. MRADS, in combination with the new Corps' Water Management System (CWMS), lays the foundation for the automation and integration of data and watershed runoff model simulation for all Corps water management activities in the Missouri River basin.

5-01.1.1. Data is collected at Corps sites through a variety of sources and integrated into one verified and validated centrally located database. The basis for automated data collection is the satellite Data Collection Platform (DCP). The DCP is a computer microprocessor physically located at the gage site. A DCP has the capability to interrogate sensors at regular intervals to obtain real-time information (e.g., river stages, reservoir elevations, water and air temperatures, precipitation), save the information, perform simple analyses of this information, and then transmit this information to a fixed geostationary satellite. Since all of the data is transmitted by satellite, the past problem of loss of communications during significant runoff or storm events has been eliminated. The RCC has operated and maintained a Direct Readout Ground Station (DRGS) since 1983. The DRGS collects DCP-transmitted, real-time data directly from the west Geostationary Orbiting Environmental Satellite (GOES) System operated by the National Oceanic and Atmospheric Administration (NOAA). The Corps' Omaha and Kansas City Districts also collect specific data using a different transmission component of the NOAA system – the DOMestic SATellite (DOMSAT). The DOMSATs at the two District offices are also referred to as Local Readout Ground Stations (LRGS). An Oracle database, maintained by the RCC, is used to store, validate, and integrate all data. The data is also available to the two District water control offices. Each of the three water management offices in the Corps' Missouri River basin area of the Northwestern Division (NWD) has an independent, current copy of the database available on a local computer system to provide a high degree of reliability. Data that are updated or revised at any of the three offices are quickly replicated at each of the other sites' databases. This system has proven invaluable during many critical events in providing water managers and other decision-makers with dependable, reliable, and accurate real-time data to assist in making significant water management decisions. Other components of the system include the Corps' communication network for inter-office communications and the highly reliable and redundant UNIX computer systems connected with both battery-powered Uninterrupted Power Supplies (UPS) and diesel-powered emergency generating facilities to assure continual operation. Preparation and implementation of a Continuity of Operations Plan

(COOP) for this system is critical to providing for redundancy and future reliability to assure success of critical data collection and modeling efforts. Plate V-1 shows the interconnection of the offices and the GOES data collection system.

5-01.2. **Data Collected.** The following paragraphs describe the data collected by the Corps to meet its water resources mission.

5-01.2.1. **Precipitation.** Historically, a relatively large number of precipitation stations were required for adequate coverage in the Missouri River basin. This precipitation station network was established and is maintained largely by the National Weather Service (NWS). The Corps had historically hired observers to report significant precipitation. Beginning in the late 1960's, this practice was phased out, and the Corps contracted with the NWS to provide precipitation data through its cooperative programs. Both the Omaha and Kansas City Districts had previously participated in this effort by providing funds to the NWS under the FC-50 and FC-33 NWS programs, respectively. In recent years, the Kansas City District has dropped their support of the FC-33 program. The Omaha District continues to fund the FC-50 program for precipitation data support. Currently, the only direct district involvement in collecting precipitation data is conducted at Corps project weather stations, and by providing automated precipitation equipment to the U.S. Geological Survey (USGS) to install and maintain at the DCP gaging sites. The introduction of automated precipitation gages at real-time DCP stations has nearly eliminated the need for observer precipitation stations in the basin. Also, data on the spatial distribution of precipitation is now provided, to a great extent, by the NWS through its Multi-sensor Precipitation Estimates (MPE). The MPE provides a 4-square-kilometer pixel format for almost all areas of the basin and are used as the primary data source for watershed modeling in the basin. The hourly MPE files are automatically retrieved from the NWS on a near real-time basis and stored on a Water Management Office's UNIX workstation. The primary purpose of the DCP real-time precipitation network is for validation of the MPE data, and for use as primary data during that portion of the runoff season when MPE data are not considered accurate. In addition, the NWS maintains a network of observed precipitation stations to provide additional point-rainfall data to validate MPE data.

5-01.2.1.1. **Station Locations.** Individual water control manuals contain maps of key hydrologic and meteorologic stations for that portion of the Missouri River basin most pertinent to regulation of the specific project under consideration. Plate V-2 shows weather stations for which meteorologic data are available more often than once daily. Data gathered through this basic network is augmented by numerous additional reports from the NWS and Corps' Districts at times of significant precipitation within the basin.

5-01.2.2. **Snow.** Nearly three-fourths of the total annual streamflow that enters the System results from the melting of the winter's snow accumulation over the northern plains area during the spring (March-April) and from the high mountain area (in combination with rainfall runoff) during the late spring and early summer (May-July) season. Flooding in the upper basin is nearly always associated with these events when the accumulation of snow is significant. Snowmelt also contributes to flood flows that occur throughout the lower basin. Measurement of the snow depth and water content of the snow cover, in combination with quantitative as well as qualitative assessments of other related data, provide insight into the potential magnitude of the flood events. This, in turn, enables System regulation to be adjusted accordingly so that flood control, as well as the other authorized project purposes, may be accomplished according to the operational objectives stated in this manual.

5-01.2.2.1. **Plains Snow.** Plains-area winter ground surveys that determine the water content of the plains snow blanket have been conducted in the Missouri River basin by Omaha District personnel during years of high plains snowmelt runoff potential since 1948. Uniform measuring and observation criteria have been established so that data from year to year will be comparable. Data pertinent to estimating runoff potential are observed at specific locations and include water content of the snow cover, snow depth, amount of ice layer present on the ground surface, a qualitative estimate of surface ground saturation, amount of drifting, and the condition of the ground surface with regard to frost penetration. In addition to the Corps' network, the NWS has a program for obtaining and reporting snow water content at selected stations in the basin and by conducting airborne gamma radiation surveys along predetermined flight lines in the upper basin. The National Operational Hydrologic Remote Sensing Center (NOHRSC) provides remotely sensored and modeled hydrology products that are used by staff to determine the expected volume of runoff from snowmelt. Sharing of these data is accomplished through the NWS Missouri Basin River Forecast Center (MBRFC) and through various NWS websites. Generally, once these data have been collected, a water equivalent map for the basin can be created. These maps have recently been digitized and sub-basin areas developed so that a history of significant plains snowmelt events is available by river basins. By comparing similar historic snow accumulations, a general estimate of the expected runoff can be developed for each tributary watershed. This technique has resulted in improved plains snowmelt runoff forecasting. As an ongoing research and development effort with the Corps' Cold Regions Research and Engineering Laboratory (CRREL), a new set of runoff models are being developed to forecast snowmelt runoff from plains areas within the Missouri River basin. This modeling system will consist of daily satellite-collected Snow Water Equivalency (SWE) data that will be integrated into a computer model utilizing a grid-cell approach. Forecasted snowmelt runoff is then routed and accumulated on a grid-cell basis. This will provide both more accurate and timely plains snowmelt forecasts that are based on daily SWE measurements rather than on data historically collected once or twice a season. Plate III-16 shows the mean annual snowfall in the basin.

5-01.2.2.1.1. **Plains Snow Surveys.** Each District office has the responsibility to stay informed of the flood potential within its drainage area at all times. Plains snow surveys within both Districts' boundaries can be made at their discretion, with inter-District coordination by the RCC. Basin-wide surveys conducted by the Districts over their established network are implemented by orders from the RCC. A partial index to the runoff potentials, upon which the implementation order is based, is obtained from available District surveys. In addition, precipitation and snow-depth reports are received throughout the winter season from various NWS stations and Corps projects. Implementation orders to the District offices include the dates, areal coverage, and minimum observation criteria for the surveys. Accomplishment of the surveys is a District responsibility. A basin-wide survey will normally be made from mid-February to early-March during those years that a moderate to heavy plains snow cover is reported. More than one survey may be implemented in any season if conditions so warrant. Reports of plains snow survey observations are forwarded by the District offices to the RCC and to the NWS MBRFC through established communication channels. Analyses of data as they affect local flood conditions and tributary reservoirs are conducted by the appropriate District water control office. The RCC evaluates the data for regulation of the System. In the event of a basin-wide survey, the RCC is responsible for combining the District reports with snow data that may be available from other sources to make a composite basin-wide analysis of the runoff potential. The RCC disseminates results of these analyses to the Districts. The analyses summary output is usually in the form of Geographic Information System (GIS) pixel layers that graphically represent the SWE over the affected areas. This information can also be used as input into watershed runoff models to represent the volume of flow expected from snowmelt. Over a period of years, these manually-measured plains snow surveys are expected to be phased out in favor of a new NOAA satellite-based system that will provide continual monitoring of plains snow accumulation. The RCC is working cooperatively in the research and development efforts on this new system and plans to incorporate the new system into its watershed runoff modeling efforts (CWMS) when it becomes available.

5-01.2.2.2. **Mountain Snow.** Manually measured snow surveys in the mountainous areas above the Fort Peck and Garrison projects date back to 1934; however, the network has changed considerably since that date. Of the snow courses most pertinent to System regulation, 60 are located in the drainage area above Fort Peck (45 are SNOw TELemetry (SNOTEL) automated sites) and 80 are located in the Yellowstone River basin (45 are SNOTEL automated sites).

5-01.2.2.2.1. **Manually Measured Snow Courses.** Surveys are conducted through the cooperative efforts of many Federal and State agencies and private entities. The Natural Resources Conservation Service (NRCS) of the Department of Agriculture has the primary responsibility for coordinating mountain snow surveys in the western United States. Manually measured mountain snow surveys are normally conducted near the first of each month during the January - June period along specified courses. The frequency of sampling varies from course to course. Most courses are measured near the first of March and the first of April when the snow cover is near the maximum. Only a few courses are sampled each month through the entire January-June period. Observations consist of measuring snow depth and water content in inches and noting qualitative data regarding ground conditions. The NRCS has phased out many of the manually measured snow courses over the years due to the high costs of conducting such data collection. The SNOTEL network primarily consists of real-time data collection from snow pillows, with just a few key locations manually measured for quality control and field verification.

5-01.2.2.2.2. **Automated SNOTEL Stations.** Automated SNOTEL pillows have been installed at various mountain locations in the Missouri River basin by the NRCS. These snow pillows, which measure the density of the snow on them, are linked to a telemetry network that is implemented and maintained by the NRCS. Snow water content and other meteorologic information are relayed to a center via meteor-burst technology. The data is subsequently verified and cross-checked with manually measured data by NRCS personnel. The SNOTEL and snow course data are entered into a NRCS database. The data are available via the NRCS web sites and the NRCS database, both of which can be accessed by the RCC. This network of data is used to provide information to determine the amount of SWE in the mountain snowpack in the Missouri River basin. Once the SWE is known, various techniques are used to determine the expected volume of runoff that will be produced. Over the years, real-time SNOTEL stations have replaced the manually measured stations and snow courses to the extent that the RCC exclusively uses real-time SNOTEL data in the Corps' Missouri River basin runoff forecast. A more detailed description of the NRCS and the SNOTEL system is available in Chapter VI, Paragraph 6-01.2.3 of this manual.

5-01.2.3. **River Stages and Discharges.** When the dams were first closed in the 1950's, river stage data were collected weekly by U.S. mail. In the early 1960s, the Corps contracted directly with individual observers. The Corps then collected the hydrologic data by telephoning these observers daily. This data collection effort was necessary to effectively regulate the System and tributary reservoirs.

5-01.2.3.1. **USGS Cooperative Program.** Over a period of years beginning in the late 1960's, the Corps began to contract out this data collection and maintenance effort to the USGS and NWS through cooperative stream gaging and precipitation network programs. The USGS, in cooperation with other Federal and State agencies, currently maintains a network of real-time DCP stream gaging stations throughout the Missouri River basin. The USGS is responsible for the supervision and maintenance of the real-time DCP gaging stations and the collection and distribution of streamflow data. In addition, the USGS maintains a systematic measurement program at the stations in order that the stage-discharge relationship for each station is current. Through cooperative arrangements with the USGS, discharge measurements at key Missouri River locations are made at a greater frequency than is normally considered adequate for historic streamflow records. Such a procedure is necessary to maintain the most current stage-discharge relationships at these stations. Current Missouri River rating curves are required to ensure that System regulation, whether geared to flood control or other authorized purposes, may proceed as efficiently as possible. Results of discharge measurements at important stations are furnished to the RCC and NWS as soon as available. The measurement results are also placed on the RCC website for District and public dissemination. Upon special request, the appropriate District arranges and furnishes discharge data for stations not included in the basic network. In addition to the stations maintained by the USGS, other Federal and State agencies, including the Corps, NWS, U.S. Bureau of Reclamation (USBR), and private entities collect stage and, occasionally, discharge data at certain locations. These additional data, if deemed useful or pertinent to System regulation, can usually be obtained from these parties by establishing appropriate data retrieval means.

5-01.2.3.2. **Non-DCP Data.** The RCC obtains most of the daily precipitation and stage data it needs for real-time System regulation directly from satellite DCPs using the GOES system, as previously discussed. The NWS, however, also distributes most of the hourly stage information used for regulation of the System over its data networks and web sites. Arrangements for the NWS reporting of stage data pertinent to System regulation are made through the NWS MBRFC in Prairie Hill, Missouri. Most of this information is available to the public via either the web or through private vendors who redistribute the information. The RCC has used both the web and private vendors for many years to provide timely graphic and text weather data for regulation of the System and for in-house briefing purposes. Maps and text are updated automatically as products are prepared and transferred on a scheduled basis. Plate V-3 shows locations of these important streamflow stations and key reservoir reporting stations within the Missouri River basin. More detailed station maps pertinent to the regulation of the individual reservoirs are presented in the individual project water control manuals. In addition to the basic network, considerable amounts of additional stream data are received, often on a seasonal or emergency basis, directly from the MBRFC. Listings and locations of these stations are presented in individual project water control manuals and in appropriate disaster manuals for flood emergency operations.

5-01.2.4. **Reservoir Data.** Reservoir data are obtained and transmitted to RCC by the Power Plant Control System (PPCS). The PPCS is explained in greater detail in Paragraph 5-04.

5-01.2.5. **Evaporation Data.** Evaporation data are particularly significant on the very large System. The average annual water loss due to evaporation at Fort Peck Lake since the System became fully operational (1967 to 2002) is 692,000 acre-feet; Lake Sakakawea is 903,000 acre-feet; Lake Oahe is 932,000 acre-feet; Lake Sharpe is 183,000 acre-feet; Lake Francis Case is 253,000 acre-feet; and Lewis and Clark Lake is 92,000 acre-feet. A standard Class "A" evaporation pan is in operation at each Mainstem reservoir. Daily manual observations of evaporation depth, pan wind movement, and pan temperature are made from April through October. Observations are not made during the other months because the pan water freezes. Based on the observed pan readings, a reservoir evaporation coefficient is computed and used to determine the daily loss of storage due to evaporation. The evaporation rate in inches per day is manually entered into the PPCS at each project. Additional data pertinent to evaporation measurement are collected from instruments co-located in the weather yard near the evaporation pan: daily minimum and maximum air and pan temperature and hourly precipitation, wind speed, and wind direction. The RCC is working cooperatively with the CRREL to automate the data collection and calculation of the daily evaporation at the System projects.

5-01.2.6. **Air Temperature Data.** Air temperature is an important meteorological parameter used in the regulation of the System. Snowmelt and ice formation can be anticipated by observing air temperature readings. Air temperature, along with wind speed, wind direction, and precipitation, are recorded hourly at each project using automated weather equipment. The data are supplied to the RCC via the PPCS network. In addition to the data collected at the projects, regional air temperature data are obtained hourly from the NWS via satellite that is displayed via a computer-based weather display system leased from Meteorlogix Company. Data is also available on various public Internet sites. Air temperature and wind velocity data is critical for accurate prediction of river ice formation. Regulation of the System to ensure adequate water supply and to prevent flooding is based on forecasts of river ice formation. Air temperature data is also important during the summer months when river water temperatures can exceed established water quality standards under low-flow conditions on the Missouri River.

5-01.2.7. **Tailwater Temperature Data.** The river water temperatures just downstream of the System dams usually vary from the mean air temperatures due to the large amount of water in storage in most of the System reservoirs. While this tailwater temperature is an important water quality parameter, it is of most concern to the regulation process as an index to surface water temperature, an important element in the development of evaporation estimates. Tailwater temperature is also an important element in predicting downstream water temperatures and for estimating formation and movement of the ice cover below the projects. Automated tailwater temperature measurements are made on an hourly basis at each of the Mainstem reservoir projects via the PPCS and are retrieved by the RCC. These data are an important element of the daily reports furnished by the RCC.

5-01.2.8. **River Reconnaissance Data Collection.** While the conditions expected to result from regulation of the reservoirs can be estimated or modeled through empirical means developed from past experience, verification requires accurate field observations. Project personnel make numerous reconnaissance trips to portions of the Missouri River that are affected by project releases and of the reservoirs to obtain information pertinent to System regulation. During the winter season, observations of ice conditions in the Missouri River are sometimes requested at critical locations. In recent years, video cameras have been located in remote areas with limited access. The cameras provide valuable river condition information through Internet access over the World Wide Web. Effects of unusual release rates or reservoir levels are also documented by field observations. Bank erosion below projects is also a matter of concern. The reconnaissance trips consist primarily of visual observations and verbal reports to the District office and the RCC. The trips are supplemented with photographic imagery when conditions warrant. When particularly unusual events occur, aerial photography or video imagery may be also scheduled. Normally, the District office coordinates and contracts for the acquisition of the aerial photography or video imagery. If aerial photography or video imagery is conducted to observe ice cover, the photography or video is shared with the local NWS Weather Forecast Offices (WSFO) so that all Federal agencies can use the results.

5-01.3. **Responsibilities for Data Collection, Analysis, and Dissemination.** The Districts are responsible for making appropriate arrangements to ensure adequate hydrologic coverage within their respective boundaries. In addition to the requirements for regulating the System, these data are essential for the Districts to accomplish their water resources mission of tributary reservoir regulation, discharge forecasting, and emergency operations on both the main stem and tributaries. Pertinent data collected by the Districts are immediately forwarded to the RCC through established communication channels. In addition to data received from the Districts, the RCC has weather and climatic products transmitted directly to the office over a satellite link by Meteorlogix Company. The RCC also maintains direct contact, either by telephone or email, with the NWS, NRCS, USGS, USBR, Western Area Power Administration (WAPA), U.S. Fish and Wildlife Service (Service), U.S. Coast Guard, and many other agencies and individuals who provide hydrologic and other data integral to the regulation of the System reservoirs. In some cases, arrangements are made with these agencies to receive data considered necessary for efficient regulation of the System and for staff supervision of the regulation of tributary reservoir projects.

5-01.3.1. All received data are directly stored in a raw unverified format to both the MRADS and CWMS databases that can be accessed by all water management staff. Automated computer programs are run on an hourly basis to complete a first-run check of the raw data. In addition, water management staff manually verify the data accuracy several times each day. These verified data are used to make scheduling decisions regarding release rates from the System and tributary reservoirs. Both MRADS and CWMS systems allow for the graphical representation of all pertinent data. The graphical representation of river flow hydrographs allows water management staff to quickly determine if the data are accurate and establish basin streamflow patterns. These data are then integrated into various runoff scenarios so that multiple reservoir simulations can be run to determine the best reservoir regulation to schedule to meet the operational objectives stated in this manual. Data can be displayed on individual water control management computers and are posted to a website for public dissemination. The database and graphics are continually updated to provide the water management staff and public with the most up-to-date information.

5-01.3.2. **RCC Briefings.** Weekly briefings, or more often, should conditions warrant, are held in the RCC for key personnel. During these briefings, pertinent basin hydrologic and meteorological information is discussed and short-term and long-term System regulation decisions are made. In addition, other meetings or telephone conferences are scheduled as necessary to keep decision-makers abreast of significant or changing conditions related to water management.

5-01.3.3. **Off-Duty Hours.** RCC water control managers also have the capability to view data and run hydrologic runoff models from their homes via high-speed Internet connections. This allows the water management staff to effectively manage the System during anytime of the day or night, including holidays and weekends.

5.02. **Water Quality Stations.** Several water quality monitoring programs have been established for the System and the Missouri River. There is no comprehensive, integrated monitoring and reporting program for the entire Missouri River basin between the Federal agencies and the individual States. The collection and storage of water quality data has been achieved on an irregular basis by numerous Federal and State agencies. The Corps has conducted long-term fixed station monitoring, intensive surveys, special studies, and investigative monitoring on selected river reaches and at all the System reservoirs. This monitoring was been conducted in the past to meet annual water quality reporting requirement and recently to facilitate preparation and implementation of project-specific water quality management plans. Water quality data collected by the Corps is available on the United States Environmental Protection Agency (EPA) STORET website (www.epa.gov/storet) and by contacting the Omaha District's Water Control and Water Quality Section. The USGS has collected water quality data on the System and Missouri River under its National Stream Quality Accounting Network (NSQAN) and Cooperative Water Programs. This data is available on USGS's website (www.waterdata.usgs.gov/usa/nwis/sw) and some locations are shown in Table V-1. The USGS also conducts water quality monitoring at selected locations in the Missouri River basin as shown on Table V-1. The Corps and the USGS maintain 49 active monitoring locations on the System and the lower river. The Corps maintains 25 of the sites and the USGS operates 24. The EPA has collected water quality data on the System under the Environmental Monitoring and Assessment Program (EMAP). Basin states have collected water quality data on the System and Missouri River to meet their monitoring and reporting requirements pursuant to the Federal Clean Water Act. State agencies that can be contacted for water quality information include: Montana Department of Environmental Quality, North Dakota Department of Health, South Dakota Department of Environment and Natural Resources, Nebraska Department of Environmental Quality, Iowa Department of Natural Resources, Missouri Department of Natural Resources, and Kansas Department of Health and Environment.

5-03. **Sediment Stations.** The Omaha and Kansas City Districts operate 13 suspended-sediment sampling stations. Seven of these stations are located on the Missouri River at Landusky, Montana; Sioux City, Iowa; Omaha, Nebraska; Nebraska City, Nebraska; St. Joseph, Missouri;

Kansas City, Missouri; and Hermann, Missouri. The remaining six stations are tributary stations at the Musselshell River at Mosby, Montana; Yellowstone River at Sidney, Montana; Bad River at Ft. Pierre, South Dakota; White River at Oacoma, South Dakota; Osage River above Schell City, Missouri; and the South Grand River near Clinton, Missouri. All sampling is conducted by, or in cooperation with, the USGS. Table V-2 presents a summary of the sediment sampling stations within the Missouri River basin.

5-04. **System Hydrologic Data Collection.** The following paragraphs describe the retrieval of hydrologic data for regulation of the System.

5-04.1. **System Reservoir Data.** Each of the System projects report data via the PPCS. Data is retrieved on an hourly basis and written to the MRADS and CWMS databases. Hourly data retrieved from the PPCS are air temperature, elevation, hydropower generation, tailwater elevation, spillway flow, turbine flow, and wind direction and speed. In addition, daily values retrieved once per day from the PPCS include total energy, average head (difference between the reservoir elevation and the tailwater elevation), pan evaporation depth, pan wind movement, average spillway flow, average turbine flow, minimum and maximum air and pan temperatures, precipitation, and turbine-flow water temperature at the tailrace. RCC staff can also access the PPCS system directly to observe current, instantaneous project operational and daily historic data. This system is very useful to monitor project releases and schedule changes during critical periods and allows confirmation that project release changes have been made in accordance with RCC orders. Similar reports from tributary reservoirs that may affect System regulation are furnished daily by the District offices. Other Federal, State, and local agencies, primarily the USBR, who are responsible for regulation of non-Corps reservoir projects, furnish reports to the RCC when their operations affect System regulation. Monthly reports, which include tabulations of inflow, releases, pool elevations, storage, evaporation losses, and other pertinent factors, are prepared by the RCC for each of the System projects. Similar reports are furnished by the Districts for each of the Corps and USBR tributary reservoirs in which the Corps has an interest. These reports are entered into the MRADS system as soon as practicable following the end of each month. The reports, sometimes referred to as MRD Form 0168, are all available to the public via the RCC's web page. A sample of such a report is shown on Plate V-4.

5-04.2. **System Databases.** MRADS and CWMS are the primary databases used to facilitate System regulation.

5-04.2.1. **Missouri River Automated Data System.** MRADS is a computer-operated, on-line, centralized database that has been in operation since 1978 for storing and disseminating Missouri River basin real-time water management data. Several times each day, the current river and project water management data are entered into MRADS via computers in the RCC and District water management offices. These data are maintained in an Oracle database with approximately 365 days of current data immediately available. Each month, the most recent month's data are added to an historic data file that is available on-line to enable quick access. Once the most recent month's data are added, the oldest month of data is removed from the file, making space available to store the current month's data. The MRADS data are archived on a regularly scheduled basis and a copy of the file is stored offsite for protection. This ensures continuity of

Table V-1

Water Quality Monitoring Stations in the Missouri River Basin

Agency	Location	Type
COE-OMAHA	Fort Peck Lake at Hell Creek	Ambient Lake
COE-OMAHA	Fort Peck Lake near Dam	Ambient Lake
COE-OMAHA	Fort Peck Lake Releases	Ambient Stream
COE-OMAHA	Lake Audubon at Snake Creek	Ambient Lake
COE-OMAHA	Lake Audubon Deepwater near Dam	Ambient Lake
COE-OMAHA	Lake Francis Case near Dam	Ambient Lake
COE-OMAHA	Lake Francis Case near Elm Creek	Ambient Lake
COE-OMAHA	Lake Francis Case Releases	Ambient Stream
COE-OMAHA	Lake Oahe near Dam	Ambient Lake
COE-OMAHA	Lake Oahe near Pollock, South Dakota	Ambient Lake
COE-OMAHA	Lake Oahe Releases	Ambient Lake
112WRD-USGS	Lake Sakakawea above Little Missouri River, ND	Ambient Lake
112WRD-USGS	Lake Sakakawea above Van Hook Arm, ND	Ambient Lake
112WRD-USGS	Lake Sakakawea at Beaver Creek Bay, ND	Ambient Lake
COE-OMAHA	Lake Sakakawea at Garrison Dam	Ambient Lake
112WRD-USGS	Lake Sakakawea at Douglas Creek Bay, ND	Ambient Lake
112WRD-USGS	Lake Sakakawea at Lewis and Clark Bay, ND	Ambient Lake
COE-OMAHA	Lake Sakakawea at Newtown, ND	Ambient Stream
112WRD-USGS	Lake Sakakawea at Riverdale, ND	Ambient Lake
112WRD-USGS	Lake Sakakawea at White Earth Bay, ND	Ambient Lake
112WRD-USGS	Lake Sakakawea near New Town, ND	Ambient Lake
COE-OMAHA	Lake Sharpe Releases	Ambient Stream
COE-OMAHA	Lake Sharpe near Dam	Ambient Lake
COE-OMAHA	Lewis and Clarke Lake near Dam	Ambient Lake
COE-OMAHA	Lewis and Clarke Lake near Springfield	Ambient Stream
COE-OMAHA	Lewis and Clarke Lake Releases	Ambient Stream
112WRD-USGS	Missouri River at Pierre, SD	Ambient Stream
112WRD-USGS	Missouri River at Yankton, SD	Ambient Stream
112WRD-USGS	Missouri River at Bismarck, ND	Ambient Stream
112WRD-USGS	Missouri River at Fort Benton, MT	Ambient Stream
112WRD-USGS	Missouri River at Garrison Dam, ND	Ambient Stream
112WRD-USGS	Missouri River near Williston, ND	Ambient Stream
112WRD-USGS	Missouri River at Toston, MT	Ambient Stream
112WRD-USGS	Missouri River at Virgelle, MT	Ambient Stream

Agency	Location	Type
112WRD-USGS	Missouri River below Fort Peck Dam, MT	Ambient Stream
112WRD-USGS	Missouri River blw Hauser Lake near Helena, MT	Ambient Stream
112WRD-USGS	Missouri River blw Holter Dam, MT	Ambient Stream
112WRD-USGS	Missouri River near Culberston, MT	Ambient Stream
112WRD-USGS	Missouri River near Great Falls, MT	Ambient Stream
112WRD-USGS	Missouri River near Landusky, MT	Ambient Stream
112WRD-USGS	Missouri River near Ulm, MT	Ambient Stream
112WRD-USGS	Missouri River near Wolf Point, MT	Ambient Stream
COE-OMAHA	Monitor at Big Bend Powerhouse	Ambient Lake
COE-OMAHA	Monitor at Fort Randall Powerhouse	Ambient Lake
COE-OMAHA	Monitor at Garrison Powerhouse	Ambient Lake
COE-OMAHA	Monitor at Gavins Point Powerhouse	Ambient Lake
COE-OMAHA	Monitor at Oahe Powerhouse	Ambient Lake
COE-OMAHA	Monitor at Fort Peck Powerhouse	Ambient Lake
COE-OMAHA	Powerhouse outfall at Pierre, SD	Ambient Lake
11NPSWRD-USGS	Yankton Raw Water Intake at Meridian Bridge	Ambient Stream
COE-OMAHA: Corps of Engineers – Omaha District Monitoring Sites 112WRD: USGS Monitoring Sites 11NPSWD: USGS Monitoring Sites Source: EPA, 2001 and Corps, 2000		

operation in case the primary file is destroyed. Also, the RCC keeps the master copy of the centralized water management database and each District maintains a copy of this database locally to provide greater reliability if network capability is lost or degraded. The Districts make frequent updates to both the local and master databases, especially during flood events, to ensure that all water management staff is using the same data. MRADS also includes static data such as reservoir elevation-storage tables, project storage allocations, river station stage-discharge tables, river routing coefficients, and river station miles. As its development continues, CWMS will replace a portion of the existing MRADS system. The RCC anticipates that CWMS will be incorporated over the next few years into day-to-day operations.

5-04.2.2. **Corps Water Management System.** CWMS is a client-server system recently developed by the Corps' Hydrologic Engineering Center (HEC). CWMS utilizes the Sun Solaris platform on the server side and the Sun Solaris and Windows 2000 platforms on the client side. CWMS involves the retrieval and storage of time-series data into an Oracle database, data verification and transformation of the data, the development and use of an array of hydrologic models to determine streamflow, reservoir operations and downstream impacts from project releases (stage and damage), the visual display of edited and transformed data and model results, and dissemination of data to web applications. In its full-functioning mode, the three water control offices will synchronize their CWMS Oracle databases. Any change made to a database in any of the three offices will immediately be "replicated" to the other two databases. The CWMS Oracle databases will not only include the various time-series data retrieved from DCP

Table V-2
Sediment Sampling Stations in the Missouri River Basin

Water Resources Regions & Streams	Location	Drainage Area (Sq. Mi.)	Period of Record	Sample Equipment and Type	Sample Frequency	Station/Purpose
Missouri River	Nr. Landusky, Montana	40,987 (1) 18,221 (2)	Oct 1968 to Date	D43 1-3/1di Str	G-S	Fort Peck Lake O&M
Musselshell River	Mosby, Montana	7,846 (1) 7,846 (2)	Oct 1981 to Date	D43 1/1di Str	G-S	Fort Peck Lake O&M
Yellowstone River	Sidney, Montana	69,103 (1) 46,448 (2)	Jun. 1937 to Date	P46 1-3/1di D43 1-3/1di BMH60 1-3	G-S	Lake Sakakawea O&M
Bad River	Ft. Pierre S. Dakota	3,107 (1) 3,107 (2)	May 1947 to date	D43 1/1di D49 1/1di Str	G-S	Lake Sharpe O&M
White River	Nr. Oacoma, South Dakota	10,200 (1) 10,200 (2)	May 1939-May1942 Mar 1944-Sep 1976 Oct 1979 to Date	D43 1/1di		Lake Francis Case O&M
Missouri River [1]	Sioux City, Iowa	314,600 (1)	Oct 1954 to date		G	
Missouri River [1]	Omaha, Nebraska	322,800 (1)	April 1939 to date		G	
Missouri River [1]	Nebraska City, Nebraska	410,000 (1)	May 1951 to date		G	
Missouri River [1]	St. Joseph, Missouri	424,300 (1)	Jun 1948 to date	P61A 1-5/1di 5-5to7P BM54.5	M	Navigation Monitoring
Missouri River [1]	Kansas City, Missouri	489,200 (1)	May 1948 to date	P61A 1-5/1di 5-5to7P BM54.5	M	Navigation Monitoring
Missouri River [1]	Hermann, Missouri	528,200 (1)	Aug 1948 to date	P61A 1-5/1di 5-5to7P BM54.5	M	Navigation Monitoring
Osage River	Abv Shell City, Missouri	5,410 (1)	Feb 1991 to date	D-76 1/1di	D	Inflow to Truman Lake
South Grand River	Nr Clinton, Missouri	1,270 (1)	Apr 1991 to date	D-76 1/1di	D	Inflow to Truman Lake

Note: Stations are operated and records published by the USGS

<u>Sampling Equipment</u>
D43 D49 P46 — Suspended Samplers
Str — Straub Bed Sampler
BMH60 BM — Bed Sampler

<u>Sample Types</u>
1-3/di — One to three verticals/one depth
1/1di — One vertical/one depth integrated

<u>Sampling Frequency</u>
G - Samples depending on discharge
S - Surface Samples
M - Monthly
D - Daily

<u>Drainage Area</u>
(1) Total Drainage Area
(2) Net Sediment Contributing Drainage

1 –Sediment sampling was suspended at the Sioux City gage in FY 2001 due to funding constraints. Data will be collected on a rotating schedule at the Omaha, Nebraska City, and Sioux City gages.

and non-DCP stations, but will also include complimentary data such as images, descriptions, and paired data (e.g., stage-discharge, elevation-storage and stage-damage tables). The development of CWMS in the RCC and District water management offices has been ongoing since the late 1990's. Because the database is such an integral part of the regulation of the System, the RCC is proceeding very cautiously in its development and ultimate implementation of CWMS as its primary database management system.

5-05. **Communications Network.** The following paragraphs describe the communication network infrastructure between the three Corps offices responsible for regulating the System and tributary reservoirs in the Missouri River basin.

5-05.1. **Physical Description.** The global network of the Corps consists of private, dedicated, leased lines between every Division and District office worldwide. These lines are procured through a minimum of two General Service Administration (GSA) approved telephone vendors, and each office has a minimum of two connections, one for each vendor. The individual links consist of either dedicated point-to-point circuits or dedicated point-to-frame relay cloud Points of Presence (POPs). The primary protocol of the entire Corps network is Ethernet. Plate V-5 shows the physical communications network of the Missouri River basin. Plate V-1 shows the data acquisition and network interconnections.

5-05.2. **Reliability.** The reliability of the Corps' network is considered a command priority and, as such, supports a dedicated 24/7/365 (24 hours per day, 7 days per week, 365 days per year) Network Operations Center (NOC). The NOC, physically located in Portland, Oregon, maintains operational status of the network. This team coordinates with all local telephone vendors as outages occur and informs local information technology staff of problems and solutions. The NOC has full control of all routers, firewalls, Channel Service Unit/Data Service Unit (CSU/DSU), and any other communication equipment that is required to connect the local office to the Corps' backbone network. This approach mitigates the risk of any office being cut off from the global network for command and control purposes. The use of multiple telephone companies supplying the network connections minimizes the risk of a one cable cut causing an outage for any office. This dual redundancy, plus the use of satellite data acquisition, makes for a very reliable water control network infrastructure.

5-05.3. **Local Operations.** The local office network operations begin at the demarcation point of the global network. This is usually the firewall output port of the global network. From this point, all network control is designed and maintained locally to meet the needs and mission requirements of each office. For the water management mission, the network is treated as a separate entity. This ensures that a local network outage, planned or unplanned, does not disrupt daily regulation of the System by the RCC or by the District offices, who regulate the tributary reservoirs in the Missouri River basin. Each Corps office is designed to exist without the other network resources. This is accomplished with the segmenting of the RCC computers and staff to use dedicated Ethernet equipment rather than to be consolidated into the general office Local Area Network (LAN). The RCC can, therefore, operate independently of the general office network. This design allows data acquisition and review to take place within the finite network of the water management LAN.

5-05.4. **Emergency Power.** The RCC is a critical component of the emergency operations plans of each District. The RCC has to be able to function in cases of flooding or other disasters, which typically are followed by the loss of commercial electricity. Because the RCC LAN is identified as separate from the office network backbone, this critical equipment is connected to both UPS and either dedicated or rapidly deployed emergency power generation equipment. A diesel-powered generator is physically located at the RCC, and is tested on a regular basis. Commercial fuel companies or Army fuel depot units, in the case of extended electrical outages, can be used to fuel the generator. The division office location has the generator and automatic transfer switch in operation 24/7/365 to maintain one command and control point in the basin for all water management needs. The District offices have large truck-mounted generation equipment that can be rapidly deployed and placed into service should an extended power outage occur.

5-05.5. **Typical Equipment.** Because the Corps' network is based on the Ethernet protocol, many different devices are used to implement the physical layer interconnection between device and network. The typical RCC LAN consists of 10/100/1000 megabit Unshielded Twisted Pair (UTP) cabling to each device. The cabling is connected to Ethernet switches to provide device-to-device communication. The switches are connected to the corporate firewall appliances, which are then connected to the physical phone network by routers and a telephonic specialized device called a CSU/DSU. The CSU/DSU is the demarcation point of the network. From this point forward the network is treated the same as standard telephone circuits by the telephone vendors who are providing the dedicated service to the Corps.

5-06. **Communication with Projects.** The following paragraphs describe the communication between the RCC and the System projects.

5-06.1. **Regulating Office with Project Office.** The RCC is the regulating office of the System. Communication between the RCC and System project offices is normally through daily reservoir and power production orders. Daily reservoir regulation and power production orders are sent by email from the RCC to the System project offices. These orders usually specify the daily average individual System project releases to be made. Scheduled power generation and maximum allowable tolerances or limits are also included in the order. Maximum hourly generation is also included, recognizing current head conditions and number of available units. Any additional release requirements, such as minimums, steady releases, or release patterns for threatened and endangered species operations, are also outlined in the order. In some cases, when no changes in releases are likely to occur at a particular project, orders may be sent to cover a period of several days. Normally, project orders are sent on Friday to cover the weekend period of project regulation, but the weekend worker will change these if deemed appropriate. In the event of loss of network communications, orders can be given via telephone.

5-06.1.1. **Standing Orders.** Standing orders are regulation orders that provide general and continuing guidance to the System projects above and beyond that contained in the daily regulation orders. For example, standing orders may specify minimum permissible generation for varying durations of time from 1 to 12 hours, maximum release fluctuations, and similar regulating limitations. When appropriate, standing orders are referenced in the daily regulation orders to avoid repeating this guidance in each order.

5-06.1.2. **Critical Regulation Periods.** During critical reservoir regulation periods and to assure timely response, significant coordination is often conducted by telephone between the project office and the RCC. This direct contact assures that issues are completely coordinated and concerns by both offices are presented and considered before release decisions are made final by the RCC. The Chief of the RCC is generally available by cell phone as are several of the Project Operations Managers. The RCC weekend worker also carries a cell phone and has the responsibility of notifying the appropriate RCC staff so that proper coordination has occurred before significant changes are made to project releases.

5-06.2. **Between the Project Office and Others.** The Mainstem project office is generally responsible for local notification and for maintaining lists of those individuals who require notification under various project regulation changes. In addition, the project office is responsible for notifying the public using project recreation areas, campsites, and other facilities that could be affected by various project release changes. A more complete discussion of project notification procedures is located in the individual project manual and the specific Mainstem Operation and Maintenance Manual, Appendix E, Contingency Plan for Emergencies for each project.

5-07. **Project Reporting Instructions.** Hourly and daily hydrologic data from the System projects are automatically transferred from the PPCS computer at each project to the RCC MRADS and CWMS databases. In the event the automatic data collection and transfer is not working, projects are required to fax or email hourly and daily project powerplant data to the RCC. RCC staff will manually input the information into the database. Monthly summaries are faxed or emailed from the individual System project offices to the RCC and are used to verify daily data.

5-07.1. Project personnel are responsible for requesting any scheduled System hydropower unit outages in excess of 2 hours. The RCC, following coordination with Western and any other affected entities, approves the request. Out-of-service times are reported back to the RCC upon completion of outages. Forced outages are also reported with an estimated return time, if possible. Any forced or scheduled outages causing the project to miss scheduled water release targets must be immediately reported to the RCC. The Mainstem project staff has been advised to contact the RCC when any unusual occurrence happens at the specific project that may affect project operations. This includes any confusion over project release schedules that have been coordinated between Western and the RCC. It is imperative that the System projects release the amount of water ordered by the RCC within the authorized tolerances.

5-08. **Warnings.** The Operation and Maintenance Manual, Appendix E, Contingency Plan for Emergencies, contains information regarding responsibilities, authority, and notification lists in the event that any warnings need to be issued. In the case of an emergency, initial in-house notification is to the District Emergency Operations Center (EOC). The EOC will, in turn, notify the District Engineer, appropriate Division Chiefs in the District, the Public Affairs Office, the NWD EOC, and the appropriate State Civil Defense Directors. Appendix E contains State Civil Defense phone numbers, maps of immediate downstream notification areas, flood inundation maps, and other pertinent information.

5-08.1. Additionally, the RCC and System project staff keep tabulations of water intakes, marinas, and other river users that could be affected by discharge changes and/or changes in river conditions. Each District's Operations Division is responsible for maintaining a contact list of navigation interests. The RCC works closely with the NWS MBRFC staff, which has the responsibility for issuing flood forecasts and warnings to the public. The Corps provides System regulation information directly to the NWS, to allow it to fulfill its responsibility to notify the public of current and expected future river conditions. In addition, the Corps consults with the U.S. Coast Guard when the Missouri River must be closed for navigation for public safety and to preserve the integrity of the flood protection structures located adjacent to the Missouri River. The final responsibility for closing the river for any purpose rests with the U.S. Coast Guard.

VI - HYDROLOGIC FORECASTS

6-01. **General.** The Corps has developed techniques and maintains staff at the RCC and at the Omaha and Kansas City Districts to conduct forecasting in support of the regulation of the System. Daily forecasting of river flow and stage is a challenging task due to the large size (529,000 square miles) of the Missouri River basin, along with the basin's hydrologic variability in climate. The Corps has developed runoff simulation and streamflow prediction models for only those areas of the Missouri River basin that have the most significant impact on the Corps' System regulation responsibilities. The System has the largest amount of storage of any reservoir system in North America. The regulation of the multipurpose System, therefore, requires the scheduling of releases and storages on the basis of both observed and forecasted hydrologic events throughout the basin. Releases to provide downstream flow support are based on providing flow levels at designated downstream locations. The accumulation and evacuation of storage for the authorized purpose of flood control is accomplished in a manner that will prevent, insofar as possible, flows exceeding those which will cause flood damage downstream. Flood risk must be considered at all times. During both normal and below-normal runoff conditions, releases through the powerplants are scheduled, to the extent reasonably possible, at the times and rates that will maximize revenue returned to the Federal Government. The release level and schedules are very dependent on current and anticipated hydrologic events. The most efficient use of water is always a goal, especially during the course of a hydrologic cycle when below-normal streamflow is occurring. Reliable forecasts of reservoir inflow and other hydrologic events that influence streamflow are critical to the efficient regulation of the System.

6-01.1. **Role of the Corps' Hydrologic Forecasting.** The System was designed for long-term conservation regulation spanning many successive drought years. The flood control and drought conservation System regulation requires accurate, continual short-range and long-range runoff, streamflow, and river-stage forecasting. The runoff forecasts are used as input in System computer model simulations so that project release determinations can be optimized to achieve the regulation objectives stated in this manual. The RCC continuously monitors the weather conditions occurring throughout the Missouri River basin and the forecasts issued by the NWS. Whenever possible, the NWS weather and hydrologic forecasts are used. The RCC develops forecasts that are to meet the regulation objectives of regulating the System and tributary reservoirs. The RCC prepares long-range runoff forecasts based on estimates of rainfall and snowmelt runoff in the basin. In addition to long-range runoff forecasting, the RCC performs short-term streamflow and river-stage forecasting to assist in scheduling System and individual project releases.

6-01.2. **Role of Other Agencies in Hydrologic Forecasting.** Several other Federal agencies have hydrologic forecasting responsibilities in the Missouri River basin. These agencies include the National Weather Service (NWS), the U.S. Bureau of Reclamation (USBR) and the Natural Resource Conservation Service (NRCS). In addition there are other Federal, State, and local agencies involved in drought and emergency operations that are, at times, providing information that is of particular interest in regulating the System.

6-01.2.1. **Role of the NWS.** The NWS is responsible for all preparation and public dissemination of forecasts relating to precipitation, temperature, and other meteorological elements related to weather and weather-related forecasting in the Missouri River basin. The

RCC uses the NWS as the sole source of information for weather forecasts. The meteorological forecasting provided by the NWS is considered critical to the Corps' water resources management mission. The use of precipitation forecasts and subsequent runoff directly relates to project release decisions. Equally important at certain times are temperature forecasts related to snowmelt and ice-jam formation. The NWS has a Weather Service Forecast Office (WSFO) at several locations in the Missouri River basin that can be contacted directly by RCC for weather-related information required to regulate the System. Currently the NWS has WSFOs at the following locations with web links that issue or disseminate local weather forecasts:

Montana	**North Dakota**	**South Dakota**	**Nebraska**	**Colorado**	**Iowa**	**Missouri**	**Kansas**
Great Falls	Bismarck	Aberdeen	Hastings	Denver/Boulder		Kansas City	Goodland
Glasgow		Rapid City	North Platte		Des Moines	Springfield	Topeka
Billings		Sioux Falls	Omaha	Grand Junction		St. Louis	Wichita
Missoula							

6-01.2.1.1. In addition, the NWS is the Federal agency responsible for the preparation and issuance of streamflow and river-stage forecasts for public dissemination. Because project regulation affects streamflows and vice versa, a close liaison is maintained between the Corps and the NWS. The Missouri Basin River Forecast Center (MBRFC), located at Pleasant Hill, Missouri, prepares forecasts for specified locations along the streams throughout the Missouri River basin. The MBRFC is also responsible for the supervision and coordination of streamflow and river-stage forecasting services provided by the NWS WSFOs located throughout the Missouri River basin. The MBRFC routinely prepares and distributes 5-day streamflow and river-stage forecasts at key gaging stations along the Missouri River from Sioux City, Iowa, to the mouth. The MBRFC also provides the Corps' District offices with flow forecasts for selected locations upon request. On a weekly basis, the MBRFC prepares a monthly forecast of river stages for the Missouri River. While both the Corps and the NWS prepare short-range streamflow and river stage forecasts, they do so for different purposes. National Weather Service forecasts include runoff from potential future precipitation to ensure that people in flood prone areas get the maximum warning possible of potential flooding. In some cases, if potential precipitation does not occur, the NWS forecast may over-estimate streamflow and river stage. The RCC forecasts only use runoff that is already being registered at the numerous stream gages in the basin, coupled with an estimate of the ungaged runoff in the numerous river reaches covered by the forecast. The RCC forecast may underestimate streamflow and river stage, if potential precipitation does actually occur. Use of both forecasts can provide a reasonable range of future streamflow and river stage. Since the NWS is responsible for public dissemination of weather-related forecasts, the Corps forecast is not made available to the public, but can be obtained by specific request.

6-01.2.1.2. The RCC obtains most of the NWS information it uses through either the NWS public network access now called Interactive Weather Information Network (IWIN) or by using LRGS data connections directly to the MBRFC. This approach has greatly improved the exchange of information via a standard format between the two agencies. In addition, this approach has resulted in a reduction in time spent on data collection exchanges between the two agencies. When questions arise concerning the validity of data or forecasts, a telephone call between respective forecasters normally resolves the issues. Inter-agency coordination meetings are conducted between offices as necessary. Other NWS systems can be used for obtaining

NWS products such as the Emergency Managers Weather Information Network (EMWIN) designated for use by State and Federal emergency managers.

6-01.2.1.3. The information provided by the MBRFC and the NWS WSFOs are used to the maximum extent possible for regulation of both System and tributary Corps reservoirs. These services are particularly useful when significant flood conditions are occurring or are imminent within the basin. The 24- and 48-hour Quantitative Precipitation Forecasts (QPFs) and severe storm forecasts are invaluable in providing guidance for System release determinations. During periods of significant basin flooding, the frequency of contacts between the RCC and MBRFC staff is increased to allow a complete interchange of available data upon which the most reliable forecasts and subsequent project regulation can be based. River-stage forecasts disseminated to the public are a NWS responsibility. The RCC conducts its own forecasting, when necessary, for System and tributary reservoir project release determinations. All Corps forecasts are not available to the general public but are shared with the NWS by allowing MBRFC staff to access these forecasts on the Corps' RCC website or by passing the information files directly to the NWS. The NWS also makes its internal forecasts available to the RCC as well as the Corps' District offices.

6-01.2.1.4. The MBRFC also issues long-term forecasts called Spring Snowmelt Outlooks. These forecasts are generally issued in February and March, with additional forecasts provided as conditions warrant. Numerical outlooks include two crest forecasts. The first crest forecast is based on a normal melt of existing snow cover. The second crest forecast is based on a normal melt of the snow cover plus normal precipitation through the melt period. Data used in preparing the Snowmelt Outlook include precipitation, snow depth, snow water content, soil moisture, ground frost, river stages and flows, and reservoir elevations. The data is disseminated by the MBRFC on Thursdays for inclusion by the WSFOs into their official public releases on Fridays.

6-01.2.2. **Role of the USBR.** Several offices in the Great Plains Region of the USBR make long-range volume hydrologic forecasts of runoff that are used for the regulation of their tributary reservoir projects in the upper Missouri River basin. The USBR offices in Billings, Montana; Casper, Wyoming; and Loveland, Colorado compute seasonal runoff forecasts for the basins in their respective states for the areas east of the Continental Divide in the Missouri River basin. The USBR uses snow water equivalent (SWE) and precipitation data collected by the NRCS and NWS. The USBR forecast models, which are based on multiple linear regressions, are developed in a similar manner to the NRCS and Corps models. The USBR models purposefully use different stations than those used by the NRCS and the Corps. The USBR generally uses average April through June precipitation in its models. Similar to the NRCS procedure, a forecaster has the option to subjectively alter the anticipated spring precipitation totals if conditions warrant adjusting for unusually wet or dry spring precipitation. The USBR compares and averages the monthly forecasts from its models with those from the NRCS and the Corps to develop a composite runoff forecast. The composite runoff forecast is then factored to minimum (80 percent), most probable (100 percent), and maximum (120 percent) confidence limits for seasonal project regulation forecasts. Similar to the NRCS, the USBR issues runoff forecast reports at the beginning of each month from January through June. Each State office computes a January 1, February 1, March 1, and April 1 forecast report that indicates most probable April through July inflows for all their major tributary basins east of the Continental

Divide. The May 1 and June 1 forecast reports indicate the same for the May through July and June and July time periods, respectively. If a tributary basin, such as the Wind/Bighorn River basins in Wyoming and Montana, crosses state lines, the two offices coordinate their forecast results before developing the seasonal project regulation forecasts. The USBR does not publish its seasonal runoff forecasts for public dissemination; however, they pass their results internally to the Corps and the NRCS via email or phone. These forecasts are furnished to the Corps District offices and the RCC. These forecasts are used by the District and RCC water managers in the regulation of tributary reservoir projects and in the integration of water supply forecasts for the Missouri River basin. The procedure of exchanging these runoff forecasts, beginning in January and extending through June of each year, has been long established in the Missouri River basin, dating back to the 1960's. The USBR is also the Federal agency responsible for providing the Corps with depletion estimates for the System that are used in long-term model simulations and to adjust current calendar year projections.

6-01.2.3. **Role of the NRCS.** The National Water and Climate Center (NWCC) NRCS office in Portland, Oregon is responsible for determining the seasonal and monthly runoff forecasts for the western United States, including the upper Missouri River basin. The NRCS field offices in Bozeman, Montana; Casper, Wyoming; and Denver, Colorado are responsible for the installation, maintenance, monitoring, and data collection of snow courses and SNOw TELemtry (SNOTEL) sites in the Missouri River basin as discussed in Chapter 5. Data for the Missouri River basin are collected at a master computer center in Portland and edited at the Bozeman and Denver offices. These offices, along with the Casper office, are also responsible for distributing the monthly forecasts and dealing directly with water users and interests. All snow courses and SNOTEL data are available on the World Wide Web. To access these data, any search engine can be used to search for "NRCS SNOTEL" or http://www.wcc.nrcs.usda.gov/, which is the Internet link to the NWCC home page. The NWCC NRCS hydrologists are responsible for issuing the seasonal and monthly forecasts, in cooperation with the NWS. The forecasts are computed at the first of each month from January through June. Updated forecasts are available at any time upon request. For the January 1, February 1, March 1, and April 1 forecasts, the NWCC hydrologists issue April through July and April through September inflows for all major tributary basins in the upper Missouri River watershed. On May 1, May through July and May through September seasonal streamflow forecasts are issued. On June 1, June through July and June through September seasonal streamflow forecasts are issued. The NRCS/NWS forecasts are available on the World Wide Web via the NWCC home page or by using any search engine to search for "NRCS Water Supply Outlook Report." The SWE and precipitation are the primary parameters used in the forecast models. To determine the pre-snowfall priming of the basin, otherwise referred to as antecedent soil moisture conditions, one of three methods may be used by the NRCS as a forecasting index. Soil moisture values are the best indicator of basin antecedent soil moisture conditions. If soil moisture values are not available for a basin, summer and early fall streamflow records from July through October are used. If neither soil moisture or streamflow records are available, summer and fall precipitation records are used. Generally, the NRCS uses data recorded as historic in their forecasts. For example, the April 1 forecast consists only of data observed and collected up to April 1. Occasionally, an NRCS hydrologist will observe that a certain spring period has the potential for unusually wet or dry conditions. In this case, the forecaster may subjectively adjust the forecast parameters to account for the unusual conditions. The NRCS forecast model results are developed using, as principal components, regression analysis. This type of analysis allows for the use of all closely located stations with closely related parameter values to be weighted and used in the forecast. The statistical regression models may be linear or nonlinear, depending on the relationship of the index parameters with the resulting streamflow. Preferably, the models are based on at least 30 years of snow, precipitation and streamflow data, using the most current data available. Through streamflow analysis and historical observations, the NRCS hydrologists have found that, for basins that are primarily snowmelt driven, seasonal runoff volumes are most highly related with the yearly peak SWE recorded at the various SNOTEL sites and snow courses. For most basins in the upper Missouri River basin, the peak snowpack is observed about mid-April of each year. The NRCS, in addition to collecting and disseminating mountain snow survey data, issues forecasts of runoff volumes. The resulting publications are furnished directly to the RCC and the Omaha District water management office.

6-02. **Flood Forecasts.** As previously discussed, the NWS has the primary responsibility to issue flood forecasts to the public. The RCC uses these forecasts as much as possible for regulating the System. The Corps also provides a link to the NWS website so that the RCC and the public can obtain this vital information in a timely fashion.

6-02.1. When hydrologic conditions exist so that all or portions of the Missouri River basin are considered to be flooding, existing Corps streamflow and short- and long-range forecasting runoff models, which are described later in this chapter, are run on a more frequent as-needed basis. This information is available to the entire Corps by providing these forecasts on the RCC internal website. The Missouri River basin is so large that the travel times are relatively long; however, many sub-basins respond quickly. Geographic diversity within such a large basin must be accounted for in any Missouri River basin-wide modeling approach. Travel time from the lowermost System project to the mouth is 10 days, as shown on Plate IV-1. Very high-runoff-producing areas exist along the Missouri River in the Big Sioux, Little Sioux, Platte, Kansas, Grand, and Ozark River basins. Those basins have much shorter travel times than the Missouri River and require continuous modeling to provide effective downstream flood control. The RCC remains cognizant of the issue of being able to quickly run forecasts during times of flooding or for other purposes. The RCC has integrated timeliness into each forecast simulation model so that the existing suite of models can perform effectively and efficiently both during normal and extreme time-constraint conditions. The currently used real-time streamflow model can be easily run in 30 minutes to provide the necessary information to determine System release scheduling. Most other models associated with runoff or streamflow forecasting for real-time regulation can perform in this same 30-minute timeframe. This short timeframe is significant. With such a large, multi-purpose System, many simulations must be run and evaluated to find the best approach to regulating the System under a range of forecasted hydrologic conditions. As greater detail is integrated into future streamflow and project simulation models to improve regulation, time of forecasting will become a more significant issue. The modeling approach is to divide the model area into smaller sub-basin areas. Only the sub-basins of the model that have significant real-time hydrologic change will be run to facilitate a quick model response time for improved decision-making. The entire basin is likely to be run in an automated fashion at certain time periods during the day to identify basins that need further evaluation. The timeliness of simulation models is tied in with RCC Continuity of Operations (COOP) plan for the water resources mission in NWD and with other prudent efforts to manage manpower and regulate the System effectively.

6-02.2. During the winter when ice jamming on the Missouri River is believed to exist, the Corps uses data from reconnaissance flights to determine the nature and extent of the ice jam to make informed release decisions. This information is shared with other Federal agencies and the public through reports and photographs available on the RCC website. Data from plains snow surveys are used to anticipate high runoff and the potential for flooding in the basin. The plains snow surveys supplement existing data and are used by the RCC to improve the regulation of the System and by the Corps' Districts for emergency operations and effective tributary reservoir regulation.

6-02.3. The individual Mainstem projects have two zones designated for flood control storage, the Annual Flood Control and Multiple Use Zone and the Exclusive Flood Control Zone. The Annual Flood Control and Multiple Use-Zone is the range of elevations in which projects normally operate under a wide range of runoff conditions. The zone designated as Exclusive Flood Control Zone is vacated most of the time and encroached upon only during significant runoff events. When individual project or System storage is great enough to occupy this zone or the Corps' simulation models forecast the projects to rise to an elevation to enter this zone, the projects are considered to be in a flood control state. When the System is in a flood control state this results in an increased frequency of forecasts and an examination of additional alternatives to return the System to a normal condition. The flood control purpose is considered foremost in this situation because of the health and human safety issues, as well as the goal of minimizing loss of property. The RCC has had a great deal of experience in performing this type of System regulation.

6-02.3.1. Several Corps reports have been published that reflect past System regulation during historically significant System flood evacuation situations (e.g., 1975, 1978 and 1997) that can be referred to for guidance. Plate VI-1 is used for guidance by the RCC in determining the service level and subsequent System release for flood storage evacuation periods. Experience demonstrates that the sooner a significant flood event can be recognized and the appropriate pre-release of flows scheduled, an improvement in overall flood control can be achieved. This situation applies mostly to the accumulation of significant mountain or plains snowpack that normally melts well after the peaking date, allowing a considerable amount of time for pre-evacuation to resolve the problem early. System storage that has accumulated from significant rainfall events must be evacuated following the event and as downstream conditions permit to provide effective flood control. While each individual System project has flood control capability, the upper three projects contain 88 percent of the total storage and are most effective in providing flood control. Also critical is the quick response in scheduling System release changes. This makes the small amount of flood control storage available in Fort Randall important as it is used to absorb these changes for a short period of time. Thus, the System has an effective regulation plan to optimize downstream flood control, which is one of the authorized project purposes. Flood Control carries the highest priority during significant runoff events that pose a threat to human health and safety and, as indicated by Plate VI-2, has provided many benefits to the Nation. Still, the area below the System is not a flood free zone. The fact that a large part of the basin is not controlled by any reservoirs results in diminished flood control effectiveness, especially in the farther downstream areas.

6-02.4. **Stage - Discharge Analyses.** Because most raw stream data are received in the form of stage information, transformation of these data to discharges is required for use in the forecasting models. Current stage-discharge rating curves are automatically obtained directly from the U.S. Geological Survey (USGS). Verification or adjustments are made as often as discharge measurements are received from the USGS. It is frequently necessary to reconcile initial estimates of discharges for streamflow stations along the Missouri River on the basis of comparison with flows at adjacent stations and reports from tributary stations. It should be noted that, while stage information is important, the System is regulated based, primarily, on discharge or flow with downstream flow targets for both flood control and other multi-purpose regulation. The determination of the correct discharge is, therefore, critical to consistent System regulation for the Missouri River.

6-02.4 1. Stage data are also required in the evaluation of System regulation effects on downstream flows. With the construction of the System, the occurrences of extreme flows (both large and small) have been reduced, particularly with large flood flows at locations that are now immediately below dams in the System. As a consequence, there is frequently no data available to define the current relationship between discharges that would have occurred without System regulation and corresponding stages. This problem is addressed in detail in the Corps' Missouri River Division (MRD) Technical Study S-73, referred to in Paragraph 8-20. This report recommends the assumption that although the stage-discharge relationship may have changed considerably since streamflow data in the required range were last observed, the slope of the rating curve through the currently undefined portions of the curve can be expected to be similar to slopes that occurred in previous years when records were available. Simplified procedures for estimating incremental stages on the basis of incremental discharges in the extreme ranges of discharge are also presented in the report.

6-02.4.2. The effect of ice cover at downstream locations is another complicating stage-discharge factor experienced in the evaluation of System regulation impacts. Construction of the System projects has altered the formation of ice at locations that are now immediately downstream from those projects. The presence, or absence, of an ice cover has a material effect on the stage-discharge relationship. Technical Study S-73 also addresses this matter and presents suggested procedures for the consideration of these effects.

6-03. **Conservation Forecasts.** Most of the time the System is regulated for normal or below-normal runoff conditions; therefore, the majority of the forecasting and runoff modeling simulation is for conservation regulation decisions. The following paragraphs discuss the forecasting and associated System modeling simulations that the Corps has developed and performs on a routine basis to meet its water resources management mission. The Corps has integrated short- and long-range forecasting as well as flood and drought System regulation into all real-time simulation models. The System is the largest reservoir system in North

America and as such, requires significant forecasting and modeling simulation efforts to achieve the operational objectives stated in this Master Manual. The data collection system discussed in the previous chapter allows for the rapid collection and assimilation of large amounts of real-time data for input into these models. The automated input of verified hydrologic data into the forecasting and simulation models is significant in allowing a greater amount of time for the RCC staff to focus on alternative regulation to achieve maximum benefits for the System.

6-03.1. **Short-Range Water Supply Forecasts.** Due to the meteorological variability of conditions in the Missouri River basin and the critical need to adjust runoff based on precipitation that has occurred at unexpected rates, short-range water-supply forecasts are frequently developed. The need of these forecasts varies, based on reservoir status and time-of-year considerations. Spring fish spawn and plains and mountain snowmelt periods often require more frequent than once monthly water-supply forecasts as does the System regulation for endangered and threatened bird species during nesting season. Large deviations in precipitation, both above and below the System, often create a need to make a mid-month or more frequent adjustment in System regulation. These forecasts generally serve the purpose of improved intra-System regulation and provide more accurate reservoir elevation and project release criteria than would be available by waiting for monthly forecasts. These forecasts are normally provided as input to the Three-Week Forecast Simulation Model, which is discussed later in this chapter. The techniques used for short-range water supply forecasting are based primarily on current basin conditions integrated with forecasted runoff, which is based on engineering judgment and experience regarding the specific basin runoff responses. The techniques used are a refinement of the previously mentioned long-range water-supply forecasting techniques. This refinement could be expected to include a greater in-depth analysis of the effects of temperature variability on expected plains and mountain snowmelt runoff and basin-wide hydrologic conditions with regard to precipitation and associated runoff. The shorter time period also allows for an adjustment for the current month of runoff because weekly runoff volumes are determined and can be integrated into the current month's forecasted runoff as a refinement. The integration of NWS Quantitative Precipitation Forecasts (QPFs) into the current Corps' Hydrologic Modeling System (HMS) streamflow forecasting model is an example of an often utilized short-range forecasting technique to determine the proper System release to meet the flood control objectives stated in this manual.

6-03.2. **Short-Range Streamflow Forecasts.** Day-to-day scheduling of releases necessary for regulation of the System on an integrated basis requires the Corps to develop daily forecasts of flows at key locations throughout the basin. These forecasts are based on observed and anticipated precipitation, temperature, temperature-snowmelt relationships, rainfall-runoff relationships, observed streamflow in the main stem of the Missouri River and tributaries, antecedent precipitation, and other factors that often may be subject to only qualitative analysis.

6-03.2.1. **District Forecasts.** The Corps' Omaha and Kansas City District water management offices also have a forecast capability and responsibility for aiding in the regulation of the System. This includes the forecasting of expected crest flows from tributary streams during periods of flood runoff. Most of these forecasts also serve the Districts in their regulation of tributary reservoir projects or in their flood emergency activities. On a routine daily basis, through the Missouri River navigation season, the Kansas City District furnishes the RCC a 14-day flow forecast for the mouth of the Kansas River on a daily basis. The Kansas City District also forecasts 14-day flows from the Osage River basin during periods of high streamflow.

6-03.2.2. **Forecasted Ungaged Inflow (FUI) Streamflow Forecasting.** The scheduling of releases from the System throughout the open-water season (generally late March through mid-December) is based on maintaining prescribed flows at downstream control points on the Missouri River referred to as “target locations” at: Sioux City, Iowa; Omaha, Nebraska; Nebraska City, Nebraska; and Kansas City, Missouri. The proper scheduling of System releases require the development of accurate forecasts of the inflows originating between Gavins Point Dam, the lowermost System dam, and the downstream target locations. Because the RCC is responsible for release scheduling from the System, it also develops forecasts of reach inflow and forecasts of flow at the target locations as a basis for release scheduling. These forecasts are developed daily for the next 14 days in the future and are compared to daily forecasts developed by the MBRFC. If significant differences in forecasts occur, an attempt is made to reconcile the differences prior to release scheduling. The ultimate forecast and scheduling responsibility for the System is, however, with the RCC.

6-03.2.2.1. The reach inflow forecasts were originally based on hand computations. These computations involved a procedure of recording observed flows at gaging locations, routing these flows to a target location, and subtracting those combined flows from the actual flow at that target location to get an “ungaged” inflow for the river reach between target locations. This procedure is carried out for five previous days of actual data and then a 14-day forecast is made of both future tributary flows at known gaging points and for the ungaged inflow into the reach. These forecasts are combined to make a 14-day Missouri River forecast that includes anticipated System releases to meet downstream target location flows. The procedure came to be known as the Forecasting Unregulated Inflow (FUI) and, subsequently, the simulation model came to be known as the FUI model. The FUI model remains an integral part of the System real-time regulation. A typical example of the output for the tributary ungaged and combined flows and resultant stages for the combined flows is shown as Plates VI-3 to VI-6. The FUI model has been modified several times over the course of its life. It uses equations developed in the North Pacific Division Streamflow Synthesis and Reservoir Regulation (SSARR) model study that is documented in MRD-RCC Technical Study O-78 Computer Program for FUI. The FUI model allows a great deal of flexibility for the forecaster to input his experience into the final Missouri River forecast. The results computed by the FUI model are adjusted utilizing the judgment and experience of the forecaster who runs the model. The FUI model only takes into account water that has reached a gaging point used in the forecast. This limitation can be significant in determining the release schedule. A significant rain that has not reached a gaging location due to water travel time to that location is not automatically included in the FUI forecast. Rainfall can only be integrated into the forecast if the forecaster has the experience to include it by adding additional flow to that location to reflect the expected additional runoff. Also, the modeling of plains snowmelt can only be accounted for as it shows up at the gaging stations used in the model. The Corps has successfully used the FUI model for over 30 years as the primary modeling tool for determining System releases. The forecasters have used their experience plus near real-time gaging and weather information on hydrologic basin conditions as they have made FUI forecast runs. National Oceanic and Atmospheric Administration (NOAA) Multi-sensor

Precipitation Estimates (MPE) radar data and other real-time weather data are available to use as input to the daily FUI forecasts. A detailed forecast for the reach from Gavins Point Dam to the mouth of the Missouri River can be run in a 20- to 30-minute time period. This relatively short time period allows for the updating and running of additional forecasts as river and weather changes become available.

6-03.2.3. **Hydrologic Modeling System (HMS) Streamflow Forecasting.** Future streamflow modeling efforts for the System are being developed using the Corps' HMS. This is the latest modeling tool available from the Corps' HEC, and it will significantly improve two aspects of modeling of the System. First, the HMS model will use more gaging stations and, most importantly, MPE radar reflectivity data in a real-time mode. This will allow the Corps staff to use MPE radar data as input to the HMS model in real-time, which will result in a streamflow prediction model that uses distributed precipitation with a much faster watershed response time than FUI. This reduced response time is considered significant in operating for both flood control and other multi-purpose regulation using the downstream target approach. In the near term, the RCC envisions that a two-step approach will be implemented to predict streamflow. First, the MPE data will be integrated using the HMS, and then the FUI model would be used to route flows downstream. This is necessary until the new models can be correctly calibrated and verified and experience can be gained in their use. Eventually, the entire lower Missouri River basin will be modeled using the HMS model to predict runoff. It is also thought that a significant portion of the Missouri River will be modeled using the HEC River Analysis System (RAS) routing model to allow prediction of water surface profiles for the Missouri River urban areas below Gavins Point Dam. This would also allow development of flood inundation data for forecasted damage and damage-reduction information associated with flood control regulation. This information will also be used to evaluate the effects on habitat for riverine fish and endangered and threatened species along portions of the Missouri River. During drought periods, releases are set to the absolute minimum that will meet downstream targets to conserve as much water as possible in the System. The streamflow forecasting models discussed above, the FUI and HMS models, have been developed and tailored to support regulation to meet the regulation objectives for the System.

6-03.2.3.1. The rainfall distribution data provided in the MPE radar data is much more reliable for both intensity and coverage compared to rainfall data obtained from single point sources as was the case in the past. The improved capability to predict watershed response is enhanced by use of the MPE radar data. The MPE radar data is collected continuously by the NWS and summed in hourly rainfall totals by local NWS radars for the entire Missouri River basin. This information is corrected and/or adjusted using observer and remote-sensing rain gages, sometimes referred to as ground-truthing, by NWS staff and provided directly to the Corps. Use of the MPE radar data has significantly improved the RCC's capability to develop reliable real-time forecasting models.

6-03.3. **Short-Range System Simulation Models.** The following paragraphs discuss the short-range system simulation models. In general, the short-range models are used both to update the long-range System models and to make daily and weekly release changes to the System. These adjustments to the release schedule generally are required to improve the storage balance between Mainstem projects or to more quickly respond to better meet the fish and wildlife enhancement operational objective with regard to fish spawning or threatened and endangered species' nesting.

6-03.3.1. **Three-Week Forecast System Model Simulation.** The Three-Week Forecast is developed using a short-range System regulation model of the same name. The model uses daily input data that is updated by the RCC on Wednesday of each week or more frequently if needed. The Three-Week Forecast presents forecasted inflows, outflows, reservoir pool elevations, and hydropower generation for a 3- to 5-week period for each of the System projects. The study serves as a guide for short-term System modifications and is used to make regulation adjustments within the range normally determined by the long-term monthly studies.

6-03.3.1.1. The power generation estimate from the Three-Week Simulation for the System is provided to Western for use in its planning and marketing. Property owners, fishermen, recreation enthusiasts, and developers use the daily pool and release forecasts from the Three-Week Forecast for a variety of purposes. Summarized data from this forecast, along with a weekly narrative on System regulation, are furnished to the System projects each week. An updated version of the Three-Week Forecast, complete with graphs and narrative, is available to the public on the RCC website.

6-03.3.1.2. The Three-Week Forecast Simulation Model is also a useful tool for comparing various regulation scenarios for specific interest requests or other requested regulation changes of short duration. Alternative current and future conditions can be simulated and individual alternative simulations can be saved and recalled at a later date for graphical or tabular comparison.

6-03.3.2. **Unsteady Flow Through a Full Network (UNET) of Open Channels Model Simulation.** The UNET model is a one-dimensional unsteady flow computer model that simulates flow in a complex network of open channels. Fluctuations of downstream river stages with varying project releases are simulated with UNET by routing flows through river reach cross-sections below Fort Peck, Garrison, Fort Randall, and Gavins Point Dams for the purpose of determining the optimum System regulation for endangered and threatened species. The other two System projects, Oahe and Big Bend, have very short river reaches below their dams to model and are signficiantly affected by downstream reservoir levels.

6-03.3.2.1. Project releases define upstream UNET boundary conditions while downstream boundary conditions are historic or forecasted reservoir elevations at the downstream Corps project (excluding Gavins Point). A stage hydrograph below the Sioux City gage serves as the downstream boundary for the Gavins Point UNET simulation model. Tributary hydrographs are input at the cross section nearest the confluence of the Missouri River and each applicable tributary. Model calibration was focused on duplicating historic water surface profiles surveyed over a wide range of steady-state releases. Input and output files are developed in an HEC-Data Storage System (DSS) format, with data displays in both a tabular and graphical format.

6-03.3.2.2. The UNET simulation models were developed for, and are used to, analyze System project release peaking patterns. The UNET models for the individual projects are used to determine the effects that these release patterns have on downstream Missouri River levels and the effects these stage changes have on interior least tern and piping plover nesting habitat below the Mainstem projects. The UNET modeling has also been invaluable for forecasting stage fluctuations at critical downstream locations during periods of high tributary flow to avoid flooding nests and chicks. The UNET simulation model is run to inform the decision-making process as releases are increased to compensate for receding tributary flows. In addition, the UNET simulation model is occasionally used for estimating stages for contractors and other specific interests at downstream locations for various project release simulations.

6-04. **Long-Range Forecasts.** Long-range forecasting has always been one of the tools that are necessary to accomplish the Corps' water management mission in the Missouri River basin. The System was constructed to serve the Congressionally authorized project purposes during an extended period of drought, such as the 12-year drought of the 1930's and early 1940's. The techniques used today were developed years ago but have been updated as improvements have occurred in computing capability and long-range forecasting techniques. In addition, many more years of System regulation experience have occurred since the System filled and became fully operational in 1967. This experience has improved the capability to develop reliable long-range forecasts. The following paragraphs describe the current long-range forecasts that are developed by the RCC to inform decisions on System regulation.

6-04.1. **Long-Range Runoff Forecasting.** Normally a significant volume of inflow into the System originates as snow. Two factors enhance the ability to conduct reliable long-range forecasts for the System. First, a considerably long period occurs between the time that the majority of the snow falls and the time it melts to produce runoff. Second, a greater percentage of the snowmelt produces runoff that eventually flows into the Missouri River because relatively little runoff is likely to infiltrate into the ground, which is generally frozen in the winter and early spring months. The accuracy of long-range forecasts is somewhat limited by abnormal hydrologic events. Generally, numerous and complex variables influence the volume of streamflow from a drainage area during any specific time period. This makes long-range forecasting difficult and decreases the accuracy. As has been the case since the System first filled in 1967, a continuous effort to improve long-range runoff forecasting will be pursued as computational capabilities and forecasting techniques continue to improve.

6-04.1.1. **Calendar Year Runoff Forecast.** The long-range runoff forecast is presented as the Calendar Year Runoff Forecast. This forecast is developed shortly after the beginning of each calendar year and is updated at the beginning of each month to show the actual runoff for historic months of that year and the updated forecast for the remaining months of the year. This forecast presents monthly inflows in MAF from five incremental drainage areas, as defined by the individual System projects, plus the incremental drainage area between Gavins Point Dam and Sioux City. Due to their close proximity, the Big Bend and Fort Randall drainage areas are combined. Plate VI-7 provides an example of the Calendar Year Runoff Forecast report format. Summations are provided for the total Missouri River reach above Gavins Point Dam and for the total Missouri River reach above Sioux City. This runoff forecast is adjusted as data becomes available to a common level of basin development, which has been selected as 1949. The 1949 development year is the most recent year that is not affected, to a great extent, by water resource development in the Missouri River basin. By adjusting runoffs to this common level of development, a consistent historical runoff data set has been created by river reach. The historic runoff data set is used to determine the effects of regulation changes by the various System simulation models. This data set can be adjusted for use in various studies to another level of basin development by applying correction factors to obtain the level of development desired.

6-04.1.1.1. Procedures for developing the Calendar Year Runoff Forecast were originally detailed in the MRD-RCC Technical Study MH-73, “Missouri River Main Stem Reservoir System, Long Range Runoff Forecasts,” dated March 1973. This technical study was updated in December 1979 to reflect the two very large runoff seasons of 1975 and 1978 as MRD-RCC Technical Report D-79. These studies were updated in 1996 to reflect the addition of 17 years of additional snow data and the additional 17 years of long-term forecasting experience. This study is referred to as MRD-RCC Technical Study D-96. This study now serves as the basis for the Calendar Year Runoff Forecast, although the previous studies have also been integrated into the latest study. This long-range forecast forms the principal basis of the “Water Supply Outlook,” which is developed monthly by the RCC from January through June and furnished via the World Wide Web to the Chief of Engineers and other interested parties. It is also used for the projections of System long-term forecast updates that are made monthly and extend through the remainder of the current calendar year plus through February of the following year.

6-04.1.1.2. More reliable seasonal forecast procedures would be very valuable in meeting the need for advance planning related to System regulation. At the present time, numerous forecasts are made for runoff anticipated from the snow that has accumulated in the mountainous areas of the basin by several agencies. Snow accumulated over the plains area is frequently a major contributor to System inflows. To date, few reliable procedures for making quantitative volume runoff forecasts for plains snowmelt are available. The RCC is working with the Corps’ CRREL, which is located in Hanover, New Hampshire, to improve existing plains snowmelt techniques and to lay the framework for the integration of future satellite remote sensing capabilities. Grid-cell-based accumulation and runoff models for plains snowmelt have been developed for the Missouri River basin that drains into the System. Future NOAA satellite-based remote sensing capability will provide a daily measure of SWE for the entire Missouri River basin. Improved plains snowmelt-runoff estimation procedures are being actively pursued. The Districts develop seasonal flow forecasts for tributary areas as an aid to tributary reservoir regulation and as a basis for the overall basin-wide evaluation of runoff potential for emergency operations.

6-04.1.2. **Annual Operating Plan (AOP) and 5-Year Extension Runoff Forecasts.** In addition to the Calendar Year Runoff Forecast, the Corps has developed a statistical technique to compute an estimate of future basin runoff using the historic annual runoff data set. This estimate allows the RCC staff to complete simulations for periods longer than just the current year. The historic annual runoff data set consists of the observed runoff for each drainage area by month beginning in 1898 through the present. This data set is then organized into a set of runoff volumes that are based on actual specific years reflected in the historical data and referred to as Upper Decile, Upper Quartile, Median, Lower Quartile and Lower Decile. To accomplish this, the years are organized from highest to lowest according to their total annual runoff volumes above Sioux City using the runoff adjusted to the 1949 level of depletions. Median runoff is developed by selecting the volume of runoff associated with an actual historic year that has 50 percent of the years having higher annual runoff volumes and 50 percent of the years having lower runoff volumes. The Upper Decile volume is selected by finding the specific year in the historic data set that is exceeded in only 10 percent of the years. Lower Decile volume is selected by finding the specific year that is represented in the historic data set that represents only 10 percent of the years having a lower volume. The same process is repeated for Upper Quartile (25 percent greater) and Lower Quartile (25 percent lower) volumes. Each of these five annual volumes is then analyzed to determine the most appropriate monthly runoff distribution by reach. This involves examining the monthly historical runoffs that have occurred in the basin and adjusting the volumes for each of these five years to get their expected monthly distributions. This technique is described in RCC Technical Report entitled, "Runoff Volumes for Annual Operating Plan Study O-98." These runoff scenarios are then used for System model simulations that, in some cases, extend as many as five additional years into the future. This allows the Corps to include data in the AOP that allows the public to look at System simulations that reflect 80 percent (between Upper and Lower Decile) of the historic runoff volumes. This provides information for planning purposes on a range of future reservoir levels and release rates. The AOP forecasts also include forecasts of water supply that will be available for the period from August 1 to March 1 of the following year. During this period of time, flows are more predictable; therefore, they can be forecast with reasonable reliability. A basic forecast of monthly inflows is made for each of the System reservoir reaches above Sioux City, which is paired with the Median forecast. Following March 1, inflows depend on many factors that cannot be forecasted at the time of preparation of the AOP. Therefore, for the AOP studies for future regulation beyond March 1 of the following year use a wide range of potential water supply scenarios, based on a statistical analysis of reach inflows during the period of record beginning in 1898. For the Upper Decile and Quartile forecasts, 120 percent of the basic forecast for August 1 through March 1 is used. Similarly, 80 percent of the basic forecast is used for the Lower Decile and Quartile forecasts. The AOP studies for future regulation, therefore, use a wide range of potential water supply.

6-04.1.3. **Long-Range System Model Simulation - Monthly Study.** The Long-Range System (LRS) regulation simulation model is routinely run on the first of each month. If significant changes occur during the current month, it may be run more frequently. Gavins Point releases to support navigation flows are determined by March 15 and July 1 System storage checks. Depending on water supply, winter releases are set by either a September 1 storage check, a minimum rate based on experience to avoid low stages downstream, or at rates as high as 24,000 cfs if evacuation of excess water in System storage continues through the winter. Intra-System releases from the other five projects are simulated to determine optimum movement of storage through the System reservoirs to satisfy authorized purposes.

6-04.1.3.1. The USBR provides streamflow depletion forecasts by river reach (excluding Big Bend) above Sioux City by August 1 of each year for use in the AOP studies described in Paragraph 6-04.1.4 in this Master Manual. These same depletion estimates are used in the LRS monthly regulation model. New Calendar Year Runoff Forecasts are prepared on the first of each month and are input to the model. Depletions are either subtracted or added to the inflows, depending on whether water is removed or returned. Reservoir evaporation is computed and subtracted from the inflows. There is no routing of project releases due to the monthly time step.

6-04.1.3.2. Western uses forecasted monthly hydropower generation for marketing purposes. The LRS model monthly forecasts are also used as a guide in scheduling unit maintenance and inspection outages and for long-term outages required for major rehabilitation of the power facilities. Property owners, fishermen, recreationists, and developers use reservoir level and project release forecasts for a variety of purposes. An abbreviated version of the monthly study is available to the public on the RCC website.

6-04.1.4. **LRS Model Simulation - AOP Study.** An AOP Study for regulation of the System has been prepared by the RCC each year since System regulation began in 1953. The AOP presents estimates of future inflows under several water supply conditions, plans for future System regulation, and expected results. The results of the AOP studies form the basis for the planned regulation of the System projects from August 1 of the current year until March 1st – two years into the future. The AOP serves as a basis for advanced coordination with the Federal and State agencies, the American Indian Tribes, the general public, and specific interests that are concerned with the regulation of the System. The AOP and monthly studies use the same computer model to simulate long-term System regulation. The AOP studies conducted to determine the expected results are based on a wide range of forecasted runoff conditions that have been previously discussed in Paragraph 6-04.1.2. in this Master Manual. Expected System reservoir releases, storages, elevations, evaporation, and power generation and capability are determined for each month for each water supply condition. Studies are made for the Median, Upper Decile, Upper Quartile, Median, Lower Quartile, and Lower Decile water supply forecasts. Selection of the monthly and annual runoff values considered appropriate for each of these water supply conditions is discussed in more detail in MRD-RCC Technical Report A-75. The studies for the year ahead are illustrative of possible System regulation that could occur rather than predictive of regulation actually anticipated.

6-04.1.4.1. Annual Operating Plan studies are prepared on August 1, based on August 1 initial conditions (starting storages, runoff forecast, and depletions) and the five runoff scenarios. These studies are finalized after input is received from the Missouri River Natural Resources Committee (MRNRC) and from State agencies and the public who attend the fall AOP Public Meetings or who provide written comments. When possible, the studies are revised to reflect these recommendations and are published in the final AOP. Five-year extensions to the Median, Lower Quartile and Lower Decile simulations are published in the final AOP. Western uses the energy forecasts shown in the extensions as a guide in making long-term energy commitments. Lower Quartile and Lower Decile extensions indicate the effects of continued below-normal runoff on project releases and pool elevations. Regulation of the System is also reviewed as part of the AOP for the calendar year and presented in a separate report entitled, “Mainstem Reservoirs Summary of Actual Operations.” Subjects covered in this review are actual water supply available; System regulation, including individual System project releases and storages; special regulation; and summary of the regulation results in terms of effects on Congressionally authorized purposes. This report also contains the System endangered and threatened species regulation and results.

6-04.1.5. **Special, Unscheduled Regulation Studies.** Special purpose studies are often made in response to inquiries from higher authority, from Congress, and from other Federal and State agencies. Additionally, throughout the year as forecasts of future runoff become available or are revised, studies are made to serve as a supplement to, and updating of, the AOP. Generally, these additional AOP-type studies are made on a monthly basis if inflow conditions depart significantly from previous studies.

6-04.1.6. **Daily Routing Model (DRM) Simulations - Master Manual Update.** The DRM was developed during the 1990's as part of the Master Manual Review and Update Study to simulate and evaluate alternative System regulation for all authorized purposes under a widely varying long-term hydrologic record. Prior to that time, the monthly version of the DRM, or the Long Range Study model, was used to review proposed changes in System regulation. The DRM uses daily input data that provides a greater level of precision that is necessary to evaluate the effects of different proposed System regulation alternatives with regard to flood control, interior drainage, groundwater, riverine fish requirements (spawning cue and shallow water habitat) on the downstream from the System, and power (capacity and energy generation) at risk in the basin.

6-04.1.6.1. The DRM is a water accounting model that consists of 20 nodes, including the six System dams and 14 gaging stations. In the DRM, each of the six System reservoirs was modeled, whereas the LRS model assumed constant elevations at the two smaller reservoirs, Lake Sharpe and Lewis and Clark Lake. The DRM provides output at four locations (nodes) along river reaches between System projects: Wolf Point and Culbertson, Montana, and Williston and Bismarck, North Dakota; and ten locations along river reaches below the System: Sioux City, Iowa; Omaha, Nebraska City and Rulo, Nebraska; St. Joseph, Kansas City, Waverly, Boonville, and Hermann, Missouri on the Missouri River and St. Louis, Missouri on the Mississippi River.

6-04.1.6.2. The historic data set used for the DRM was developed from the RCC MRADS Oracle database, USGS gaging records, and from the LRS model database for depletions and reservoir evaporations prior to 1967. Daily records are available for the six System dams since their respective dates of closure, and daily flow data is available for the majority of gaging stations since 1930. Prior to 1930, there is general lack of daily records in the basin. Representative daily data was constructed to cover the period from 1898 to 1929 because of the significance and statistical importance of the drought of the 1930's in System regulation. As a result, there are 100 years of data used in the historic data set, which extends from 1898 through 1997. The data are organized in yearly files that contain daily data for each of the dams and gage locations.

6-04.1.6.3. The DRM uses two sets of input data and a number of smaller data files. The first set of input data consists of historic reach inflows and streamflow depletions. There is also an option to include forecasted monthly runoff. The second data set contains various constants and variable parameters that define regulation decisions and operational limits for a particular simulation. These include downstream flow targets, reservoir characteristics, regulation levels, regulation guide curves, power generation criteria, navigation guide criteria, and fish and wildlife criteria, including endangered and threatened species.

6-04.1.6.4. The DRM provides options for creating a number of output files showing various parameters for each node in the model and for the System, using either daily or monthly data for the period of study. The DRM also has associated graphics programs developed to view daily or monthly data for a variety of parameters and time periods to evaluate the effects of proposed alternatives. The DRM model can be used as a real-time regulation model. As with all models, the DRM will eventually be modified or replaced by an improved regulation-modeling tool.

6-04.1.7. **Natural, or Unregulated Flows (Holdouts).** Analyses are conducted to reconstitute flows without the System for the purpose of determining reservoir regulation effects of System and tributary reservoirs regulation. These effects are computed using a program called Mainstem and Tributary Reservoir unregulated flows, or holdouts. A simple lag-average procedure is used for the routing of reservoir effects downstream to selected Missouri River main stem locations at which reconstituted, or natural flows are desired. Coefficients considered to be applicable, based on examination of flood events, are presented in MRD Technical Study S-73, "Upper Missouri River, Unregulated Flow Development." The reach locations are chosen based on length of river, taking into account streamflow attenuation, and are basically the same as those presented in the stage-damage curve reduction discussion in Paragraph 4-05.13 and Plates IV-2 through IV-13. The natural flows are used to compute annual flood damages prevented and to explain stage reductions resulting from regulation of the System to the public and other interested parties. There has been interest in recent years to make this a real-time tool, which will be possible when the CWMS software is implemented.

6-04.1.8. **System Water-Quality Modeling.** The RCC, cooperating with the Omaha District Water Control and Water Quality Section, is developing a CE-QUAL-W2 water quality model for the larger System reservoirs. CE-QUAL-W2 is a two-dimensional, unsteady flow hydrodynamic and water-quality model developed and supported by the Corps' Engineering Research and Development Center (ERDC) located in Vicksburg, Mississippi. This model has been widely applied to stratified surface water systems such as lakes, reservoirs, rivers, and estuaries. This water quality model computes water levels, horizontal and vertical velocities, temperatures, and 21 other water quality parameters such as dissolved oxygen, nutrients, organic matter, algae, pH, carbonate cycle, bacteria, and dissolved and suspended solids. The preliminary results of using a CE-QUAL-W2 model as an additional reservoir regulation tool to evaluate water quality considerations has been promising. The model has shown that it could facilitate evaluating the effects on water quality of changes in reservoir regulation and other adaptive management actions. The following are observations noted, based on preliminary CE-QUAL-W2 model results. This model can quickly demonstrate or clarify how, by changing regulation of projects' storage levels, release rates, and timing, the reservoir and downstream river water quality parameters vary. Certain real-time water quality conditions can be predicted at System projects, using real-time flows and meteorological conditions. The model can also forecast future water quality conditions based on projected future reservoir regulation scenarios using either synthetic or historic inflows and meteorological data. Finally, the model can be used simulate water quality conditions due to System regulation changes due to changes in runoff scenarios or structural changes such as intake modifications. The aspects of System regulation evaluated could include distribution of storage volumes between several reservoirs and drawing water from different elevations in the reservoir. The CE-QUAL-W2 model could then be used to measure the impact on water quality in the reservoirs by evaluating alternative types of regulation. This model could also aid in water quality data collection by identifying expected critical or sensitive water quality situations in advance that would require more extensive water quality monitoring. The model could be useful in focusing data collection on that part of the reservoir for those water quality parameters that would provide the desired information. This is especially significant on the upper three System reservoirs that are so large.

6-05. **Drought Forecast Simulation.** Over the regulation history of the System, various products have been used to detect the extent and severity of basin drought conditions. Since the System was developed to deal with consecutive years of long-term drought, no specific drought forecast has been developed. The System was designed, and the new water control plan was selected, to serve authorized purposes during a 12-year drought such as that experienced during the 1930's. The consideration of drought for short and long-term forecasting and System regulation is part of the normal forecasting process used by the RCC. Currently, a product called the Drought Monitor, which has replaced the Palmer Index as a drought reference, is used to generally determine the extent and severity of drought in the Missouri River basin. The runoff forecasts developed for both short- and long-range time periods reflect drought conditions when appropriate. The normal banding of runoff to address 80 percent of the expected runoff conditions covers significant drought and provides a reliable tool to assess the effects of drought and the anticipated System regulation. The period of record contains four significant droughts, including the two droughts contained in the record since the System first filled in 1967. This provides a good data set to guide real-time regulation during significant drought periods. As various new techniques become available and improvements are made to existing drought indicators, they will be integrated into the System runoff forecasts. Improved forecasting and the development of simulation tools will be an ongoing process in which better techniques will become available and used in all forecasting areas. The primary data source used to demonstrate System regulation during drought is the Corps' statistical runoff volumes representing Lower Quartile and Lower Decile runoffs. This data set is used as input for the System LRS simulation model to show long-term effects of System regulation under very low basin runoff. This is particularly true for AOP period simulations using the LRS model that includes the 5-year extensions of Lower Quartile and Lower Decile runoffs.

VII – CURRENT WATER CONTROL PLAN FOR THE SYSTEM

7-01. **System Water Control Plan.** In enacting the 1944 Flood Control Act, Congress adopted the recommendations contained in the underlying Pick-Sloan documents. These documents identified flood control, navigation, irrigation, hydropower, water supply, water quality, recreation, and fish and wildlife as project purposes and also provided for the protection of beneficial consumptive uses in the upper basin. Congress did not assign a priority to these purposes. Instead, it was contemplated that the Corps, in consultation with affected interests and other agencies, would balance these functions in order to obtain the optimum development and utilization of the water resources of the Missouri River basin to best serve the needs of the people. The Missouri River Master Water Control Manual Review and Update Study (Master Manual Study) was conducted without bias toward any project purpose. Therefore, no priority was assumed for any economic use or environmental resource in the conduct of that study. The result of the Master Manual Study has been the identification of the current Missouri River Mainstem Reservoir System Water Control Plan (CWCP) that is described in detail in this chapter. This chapter sets forth the detailed provisions of the selected water control plan for the System. In the event of any inconsistencies between the provisions of this Chapter VII and any other provisions of this Master Manual, this Chapter VII shall take precedence.

7-01.1. The CWCP presented in this Master Manual was developed with four objectives in mind: first, to serve the contemporary needs of the basin and the Nation; second, to serve the Congressionally authorized project purposes; third to comply with other applicable statutory and regulatory requirements including environmental laws such as the Endangered Species Act (ESA); and fourth, to fulfill the Corps' responsibilities to Federally recognized Tribes. The application of the water control plan presented in this Master Manual is designed to meet certain operational objectives during drought, flood and normal runoff periods. Many assumptions were necessary in order to effectively analyze the effects of the application of this water control plan. If these assumptions are no longer valid in the future due to changed conditions or unforeseen circumstances, the Corps will adjust the water control plan presented in this Master Manual in an attempt to continue to meet the intended operational objectives. The following paragraphs describe how the water control plan will meet the operational objectives of this Master Manual for each of the Congressionally authorized project purposes. The CWCP described in this chapter meets the objective of serving all of the Congressionally authorized project purposes of the System while considering the other short and long-term factors affecting the regulation of the System. Optimizing service to all of the Congressionally authorized purposes may be impossible at times because of conflicts between the individual authorized purposes. Therefore, optimization of benefits to individual project purposes will be pursued to the extent reasonably possible.

7-01.2. **Regulation Objectives.** As an introduction to a discussion on regulation objectives of the CWCP, the need to conform to certain basic water-in-storage provisions and basic principles of reservoir regulation of the System should be recognized, except in unusual circumstances. The Permanent Pool Zones of the System reservoirs are intended to remain permanently filled with water. This will ensure the maintenance of minimum power heads, minimum irrigation diversion levels, and minimum reservoir elevations for the water supply, recreation, and fish and wildlife purposes. Similarly, the Exclusive Flood Control Zones at the projects are provided for the regulation of the largest of floods. They will be reserved exclusively for this purpose and generally be empty. The two other storage zones that are intermediate to the Permanent Pool and the Exclusive Flood Control Zones provide active storage for project purposes. These storage zones are called the Annual Flood Control and Multiple Use and the Carryover Multiple Use Zones. These also provide storage space for the control of moderate floods and, when combined with the upper Exclusive Flood Control Zone, provide control of major floods.

7-02. **System Regulation Summary.** System regulation is, in many ways, a repetitive annual cycle. The melting of plains and mountain snow produces most of the year's runoff into the System, and spring and summer rains supplement that runoff. After reaching a peak, usually during July, the amount of water stored in the System declines until late in the winter when the cycle begins anew. A similar pattern may be found in rates of releases from the System, with the higher levels of flow from mid-March to late November, followed by low rates of winter discharge from late November until mid-March, after which the cycle repeats. The Water Control Calendar of Events, shown on Plate VII-1, presents the time sequence of many of these cyclic events.

7-02.1. Variations in runoff into the System necessitates the varied regulation plans to accommodate the multipurpose regulation objectives. The two primary high-risk flood seasons are the plains snowmelt and rainfall season extending from late February through April and the mountain snowmelt and rainfall period extending from May through July. Also, the winter ice-jam flood period extends from mid-December through February. The highest average power generation period extends from mid-April to mid-October, with high peaking loads during the winter heating season (mid-December to mid-February) and the summer air conditioning season (mid-June to mid-August). The power needs during the winter are supplied primarily with Fort Peck Dam and Garrison Dam releases and the peaking capacity of Oahe and Big Bend. During the spring and summer period, releases are normally geared to navigation and flood control requirements, and primary power loads are supplied using the four lower dams. During the fall when power needs diminish, Fort Randall is normally drawn down to permit generation during the winter period when Oahe and Big Bend peaking-power releases refill the reservoir. The major maintenance periods for the System hydropower facilities extend from March through mid-May and September through November, which normally are the lower demand and off-peak energy periods. The exception is Gavins Point, where maintenance is performed after the end of the navigation season because all three power units are normally required to provide for navigation and other downstream flow support needs. The normal 8-month navigation season extends from April 1 through December 1, during which time System releases are increased to meet downstream target flows in combination with downstream tributary inflows. Winter releases after the close of the navigation season are much lower and vary depending on the need to conserve or evacuate System storage volumes, downstream ice conditions permitting. Minimum release restrictions and pool fluctuations for fish spawning management generally occur from April 1 through July. Endangered species nesting occurs from early May through mid-August. Other factors may vary widely from year to year, such as the amount of water-in-storage and the magnitude and distribution of inflow received during the coming year. All of these factors will affect the timing and magnitude of project releases. The gain or loss in the water stored at each reservoir must also be considered in scheduling the amount of water transferred between reservoirs to achieve the desired storage levels and to generate power.

These items are continually reviewed as they occur and are appraised with respect to the expected range of regulation. The following paragraphs discuss the regulation of the individual System dams to accomplish the System reservoir regulation objectives.

7-02.2. **Fort Peck – Fort Peck Lake.** Fort Peck's primary water management functions are (1) to capture the mountain and the plains snowmelt and localized rainfall runoffs from the large drainage area above Fort Peck Dam, which are then metered out at controlled release rates to meet the System's authorized purposes while reducing flood damages in the Fort Peck Dam to Lake Sakakawea reach; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Garrison, Oahe, and Fort Randall; and (3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low-water years.

7-02.3. **Garrison Dam – Lake Sakakawea.** Garrison, the largest Corps storage reservoir, is another key player in the regulation of the System. Its primary water management functions are (1) to capture the snowmelt runoff and localized rainfall runoffs from the large drainage area between Fort Peck and Garrison Dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Garrison Dam to Lake Oahe reach, particularly the urban Bismarck area; (2) to serve as a secondary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Oahe and Fort Randall; and (3) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes that draft storage during low-water years.

7-02.4. **Oahe Dam – Lake Oahe.** Oahe's primary water management functions are (1) to capture plains snowmelt and localized rainfall runoffs from the large drainage area between Garrison and Oahe Dams that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Oahe Dam to Big Bend reach, especially in the urban Pierre and Fort Pierre areas; (2) to serve as a primary storage location for water accumulated in the System from reduced System releases due to major downstream flood control regulation, thus helping to alleviate large reservoir level increases in Big Bend, Fort Randall, and Gavins Point; and (3) to provide the extra water needed to meet project purposes that draft storage during low-water years, particularly downstream water supply and navigation. In addition, hourly and daily releases from Big Bend and Oahe Dams fluctuate widely to meet varying power loads. Over the long term, their release rates are geared to back up navigation releases from Fort Randall and Gavins Point Dams in addition to providing storage space to permit a smooth transition in the scheduled annual fall drawdown of Fort Randall. Big Bend, with less than 2 MAF of storage, is primarily used for hydropower production, so releases from Oahe are generally passed directly through Big Bend.

7-02.5. **Fort Randall – Lake Francis Case.** Fort Randall's primary functions are (1) to capture plains snowmelt and localized rainfall runoffs in the drainage area from Big Bend Dam to Fort Randall Dam that are then metered out at controlled release rates to meet System requirements, while reducing flood damages in the Fort Randall reach, where several areas have homes and cabins in close proximity to the river; (2) to serve as a primary storage location, along with Oahe, for water accumulated in the System when System releases are reduced due to major downstream flood control regulation, thus helping to alleviate large pool increases in the very small Gavins Point project; (3) to provide a location to store the water necessary to provide increased winter energy to the basin by allowing an annual fall drawdown of the reservoir to occur with a winter reservoir refilling that is unique to Fort Randall; and (4) to provide the extra water needed to meet all of the System's Congressionally authorized project purposes, particularly navigation and downstream water supply, that draft storage during low-water years.

7-02.6. **Gavins Point Dam – Lewis and Clark Lake.** Gavins Point Dam, the most downstream of the System dams, is primarily used as a re-regulating dam to level out the release fluctuations from the upper System dams to better serve System requirements. With a total reservoir storage volume of only 500,000 acre-feet, it provides very little flood control and is generally maintained in a narrow reservoir elevation band between 1205 and 1207 feet msl. Due to the limited storage, releases from Gavins Point Dam must be backed up with corresponding release changes out of the upper projects. Gavins Point is the key location in the initiation of release reductions for downstream flood control. Even though it has only a small amount of storage space for flood control, this volume is usually adequate to perform downstream flood control by coordinating Gavins Point Dam release reductions with Fort Randall's. Releases greater than the powerplant capacity are passed through the spillway

7-03. **System Regulation Techniques.** The following discussion provides basic information related to the CWCP presented in this Master Manual. The concepts discussed are the division of the individual System reservoirs into regulation zones; the provision of a level of service to meet the Congressionally authorized purposes and the associated flow targets to achieve that level of service; System water-in-storage checks; and seasonal release considerations, which include regulation during the winter and regulation for endangered species. The process of implementing this CWCP is based on selecting the appropriate System regulation criteria described in this chapter for the appropriate time of year and System water in storage (storage) or water supply (System water in storage plus anticipated runoff for the remainder of the year) condition. Normal and Conservation System regulation involves a check on the amount of System water in storage on March 15 to determine if a navigation season will be provided that year, and if so, the service level to provide for the first part of the navigation season (Table VII-2). Downstream target flows at four designated locations are used to guide System releases (Table VII-1). The System water-in-storage is checked again on July 1 to determine the service level for the remainder of the navigation season (Table VII-2) and the ending date or length of the navigation season (Table VII-3). Finally the System storage is checked on September 15 (Table VII-4) to determine the System winter release rate. The above sequence is altered slightly if the System water supply is above normal or if the System is performing a major flood control action. In that case, the service level is determined as often as required (Plate VI-1) based on actual System storage and forecasted water supply so that the System release rate can be scheduled to minimize downstream flood risk and reduce flood damages. The navigation season is extended for 10 days in higher runoff years to facilitate evacuation of flood control storage space before the next flood season. Navigation Service Level is defined as "full" or "minimum." Full Service (see Table VII-7) is provided in near-normal runoff years to provide for evacuation of flood control storage before the next flood season, while serving navigation to the full capability of the authorized 9-foot downstream channel (8.5-foot draft). Minimum Service (see

Table VII-8) is usually provided in drought times to provide a minimum level of navigation service (7.5 feet of draft) while conserving water in the System in case of an extended drought. Consideration is also given to using System Replacement Flood Control Storage in cooperation with the U.S. Bureau of Reclamation (USBR), which will be discussed in greater detail later in this chapter. Also, within the framework of the overall goals stated above, there are seasonal decisions to optimize the benefits obtained for the various authorized purposes, such as fish spawning, endangered species nesting and releases during river ice formation periods.

7-03.1. **System Regulation Zones.** The storage capacity of the System has been developed to provide beneficial service to the Congressionally authorized purposes. Regulation of a particular project for one authorized purpose may be compatible, to a varying degree, with regulation for most of the other authorized purposes. For another authorized purpose, this regulation may be detrimental. For example, the vacating of storage capacity after a flood event to assure control of possible future flood events is compatible with providing releases for power, navigation, and water supply; however, it is incompatible with the objective of providing stored reserves for continuation of these purposes during a subsequent drought period. These factors made it advisable to divide the storage in individual System reservoirs into regulation zones to obtain the maximum possible service to all of the purposes consistent with the physical and authorizing limitations of the System. Totaling the storage capacity in the respective zones of the individual projects provides the total System storage capacity available in each regulation zone for use in System regulation. These values are not fixed but vary slightly over time according to changes in reservoir capacity from sediment collection in the reservoirs and shoreline erosion. For example, when the System was first considered filled in 1967, the total storage capacity was 75.2 MAF, and as of March, 2004, total storage capacity is 73.4 MAF. This change in storage capacity has been reflected in the System storage zones by adjusting the elevations of the various storage zones within the individual projects to reflect the correct amount of storage according to the change that has occurred. In some cases, the elevations have not changed but the actual System storage number has been adjusted for that zone. The regulation zones, and the guidance criteria for regulation in these zones considered necessary to achieve the multipurpose benefits and operational objectives for which the reservoirs were authorized, are described in the following paragraphs.

7-03.1.1. **Exclusive Flood Control Zone.** Flood control is the only authorized purpose that requires empty space in the reservoirs to achieve the objective. A top zone in each System reservoir is reserved for use to meet the flood control requirements. The storage space therein is used only for detention of extreme or unpredictable flood flows and is evacuated as rapidly as soon as downstream conditions permit, while still serving the overall flood control objective of protecting life and property. Considerations to achieve the flood control objective include a release limitation for each of the projects, status of storage in the other projects and the level of System or the Gavins Point Dam release being maintained, as designated by criteria discussed later in this chapter. The Exclusive Flood Control Zone represents 4.7 MAF (the upper 6 percent) of the total System storage volume, and this zone, from 73.4 MAF down to 68.7 MAF, is normally empty. The large four reservoirs, Fort Peck Lake, Lake Sakakawea, Lake Oahe, and Lake Francis Case, contain 98 percent of the total storage reserved for the Exclusive Flood Control Zone.

7-03.1.2. **Annual Flood Control and Multiple Use Zone.** An upper "normal operating zone" is reserved annually for the capture and retention of normal and flood runoff and for annual multiple-purpose regulation of this impounded water. The System storage capacity in this zone represents 11.6 MAF (16 percent) of the total System storage volume, and extends from 68.7 MAF down to 57.1 MAF. This storage zone, located immediately below the Exclusive Flood Control Zone, will normally be evacuated to the base of this zone by about March 1 to provide adequate storage capacity for capturing runoff during the next flood season. Exceptions may occur. One example would be if System Replacement Storage were requested in conjunction with regulation of the USBR reservoirs in the upper Missouri River basin. On an annual basis, water will be impounded in this zone as required to achieve the System flood control purpose and also be stored in the interest of general water conservation to serve all the other Congressionally authorized System purposes. The evacuation of water from the Annual Flood Control and Multiple Use Zone is scheduled to maximize service to the authorized purposes that depend on the release of water from the System. Scheduling releases from this zone is limited by the flood control objective in that the evacuation must be completed by the beginning of the next flood season. This is normally accomplished as long as the evacuation is possible without contributing to serious downstream flooding. Evacuation is, therefore, accomplished mainly during the summer and fall because Missouri River ice formation and the potential for flooding from higher release rates limit System release rates during the December through March period.

7-03.1.3. **Carryover Multiple Use Zone.** A second lower intermediate zone provides a storage reserve for irrigation, navigation, power production, water supply, recreation, and fish and wildlife. The water stored in this zone at the three larger reservoirs (Fort Peck, Garrison, and Oahe) will maintain downstream flows through a succession of well-below-normal runoff years into the System. Serving the authorized purposes during an extended drought is an important regulation objective of the System and the primary reason the upper three System reservoirs are so large compared to other Federal water resource projects. The System storage capacity in this the largest storage zone represents 39.0 MAF (53 percent) of the total System storage volume and extends from a volume of 57.1 MAF down to 18.1 MAF. The Carryover Multiple Use Zone is often referred to as the "bank account" for water in the System because of its role in providing assistance to the basin during critical dry periods. Water stored in the Carryover Multiple Use Zone will be used to meet project purposes in the event that the storage in the Annual Flood Control and Multiple Use Zone is exhausted. Only Fort Peck, Garrison, Oahe, and Fort Randall have this storage as a designated storage zone. The three larger projects of Fort Peck, Garrison, and Oahe serve the Missouri River basin during drought periods and water from this zone is called upon to meet operational objectives stated in this plan. The storage space assigned to this zone in Fort Randall serves a different purpose. A portion of the Fort Randall space is normally evacuated each year during the fall season to provide recapture space for upstream winter power releases. The recapture results in complete refill of the space during the winter months. Deliberate, long-term drawdown into the Fort Randall Carryover Multiple Use Zone is not contemplated. During drought periods, the three smaller System projects (Fort Randall, Big Bend, and Gavins Point) are maintained at the same elevation they would be at if runoff conditions were normal. While a minor amount of space in Big Bend and Gavins Point was initially provided in this zone, deliberate drawdown into this zone is generally not contemplated.

7-03.1.4. **Permanent Pool Zone.** A bottom inactive zone, called the Permanent Pool Zone, provides for a minimum power head and for future sediment storage capacity. It also serves as a minimum pool for recreation, fish and wildlife, and as an assured minimum level for water access from the reservoir. A drawdown into this zone is generally not scheduled except in unusual conditions. The System storage capacity in this the lowermost storage zone represents 18.1 MAF (25 percent) of the total System storage volume (extends from 18.1 MAF down to 0 MAF). To date, this zone has been increased by the addition of storage originally in the Carryover Multiple Use Zones of Big Bend and Gavins Point. The regulation of System in the Permanent Pool Zone has been changed slightly due to the changes in the storage used in the Carryover Multiple Use Zone. The likelihood of using water stored in the Permanent Pool Zone has been reduced in the CWCP.

7-03.1.5. **Current System Storage Zone Allocations.** As of this time, the System has been regulated as an integrated system for 50 years. During this 50-year period, many regulation techniques have been evaluated. System regulation procedures have been modified to provide a plan for sustaining and balancing all of the Congressionally authorized project purposes. A basic method of evaluating proposed changes in System reservoir regulation has been the long-range System regulation study, as described in Chapter VI of this Master Manual. Numerous long-range studies have been made since 1964, and long-range study criteria have been modified so that release restrictions imposed by the flood control purpose are reflected in the studies. These many long-range studies have been supplemented by detailed examination of particularly severe flood events, which are described in detail in Appendix A of this Master Manual. The Master Manual Study included over 500 long-range studies, exceeding the total number of studies conducted prior to that time.

7-03.1.5.1. Long-term studies have also been made to investigate the effects of continued water resource development in the Missouri River basin. In general, these studies indicate that the flood control zone elevations currently used will continue being applicable well into the future. The loss of storage in the flood control zones of the System reservoirs due to sedimentation will be balanced by the reductions of flood runoff resulting from continuing water resource development, land treatment, and depletions that includes future appropriation of tribal water rights. Studies will continue to be made to determine the effects of such changes in Missouri River basin water resource development and in associated System regulation techniques. A major purpose of these studies will be the re-evaluation of System and individual System project storage zone allocations. If deemed necessary, appropriate action toward modification of System project storage zones will be initiated.

7-03.1.5.2. The current storage allocations and associated elevations in each of the zones of individual System projects, as well as for the System as a whole, is shown on Plates II-1 and II-2. Storages given in this table reflect the January 2004 elevation-storage relationships. Minor modifications from previous allocation tables are discussed below.

7-03.1.5.2.1. **Fort Peck.** The elevation of the top of the Permanent Pool Zone, or the bottom of the Carryover Multiple Use Zone, has not changed for Fort Peck; however, this updated water control plan has changed the regulation of the System during drought, or water conservation, periods. This change will result in the reservoir being approximately 22 feet higher during a drought like the 1930's; therefore, the likelihood that Fort Peck will drop to the top of its Permanent Pool Zone during its project life is reduced under this changed plan.

7-03.1.5.2.2. **Garrison.** The elevation of the top of the Permanent Pool Zone, or the bottom of the Carryover Multiple Use Zone has not changed for Garrison but it should be recognized that this updated water control plan has changed the regulation of the System during drought or water conservation periods. This change will result in the reservoir being approximately18 feet higher during a drought like the 1930's, therefore the likelihood that Garrison will drop to the top of its Permanent Pool Zone during its project life is reduced under this changed plan.

7-03.1.5.2.3. **Oahe.** The elevation of the top of the Permanent Pool Zone or the bottom of the Carryover Multiple Use Zone has not changed for Oahe but it should be recognized that this updated water control plan has changed the regulation of the System during drought or water conservation periods. This change will result in the pool being approximately 21 feet higher during a drought like the 1930's, therefore the likelihood that Oahe will drop to the top of its Permanent Pool Zone during its project life is reduced under this changed plan.

7-03.1.5.2.4. **Big Bend.** The elevation of the top of the Permanent Pool Zone or the bottom of the Carryover Multiple Use Zone has not changed for Big Bend. The Annual Flood Control and Multiple Use Zone extends between elevations 1420 and 1422 feet msl and is used for power scheduling purposes with the Exclusive Flood Control Zone extending between elevations 1422 and 1423 feet msl. The Annual Flood Control and Multiple Use Zone in Big Bend is not provided for seasonal regulation of flood inflows like the other major upstream projects, but the zone is used for day-to-day and week-to-week power operations. A settlement agreement approved in an order of dismissal by the United States District Court, District of South Dakota, in the case of Lower Brule Sioux Tribe et al. v. Rumsfeld, et al. (Civil No. 02-3014 (D.S.D.)) provides that the Corps will consult with the Lower Brule Tribe and the Crow Creek Sioux Tribe during any review and revision of the Missouri River Master Water Control Manual. This agreement also provides that the Corps will coordinate the regulation of the Big Bend Project and the water level of Lake Sharpe with the two Tribes to include the following: the Corps will normally strive to maintain a level at Lake Sharpe between elevation 1419 feet msl and 1421.5 feet msl; when the level of Lake Sharpe drops below elevation 1419 feet msl or exceeds elevation 1421.5 feet msl, the RCC will provide notice to such persons as the Tribes shall designate in writing; when it is anticipated that the water level will drop below 1418 feet msl or rise above 1422 feet msl, or in the event the water level falls below 1418 feet msl or rises above 1422 feet msl, the Commander, Northwestern Division, or his designee, shall immediately contact the Chairpersons of the Tribes or their designees to notify them of the situation and discuss proposed actions to remedy the situation.

7-03.1.5.2.5. **Fort Randall.** The Carryover Multiple Use Zone in this project is used to recapture upstream winter power releases rather than for the maintenance of a storage reserve for long-term droughts, as is provided in the three major upstream System projects. On all reservoir regulation simulations analyzed for the Master Manual Study, Fort Randall was not drawn down below an elevation of 1337.5 feet msl. This lower limit has been a regulation objective since it was first instituted in 1972. Additional details of this change are available in an RCC report entitled, "Modification of Operation of Lake Francis Case, South Dakota." The water stored in the Fort Randall Carryover Multiple Use Zone from 1320 to 1337.5 feet msl may be used and withdrawn during a drought that is more severe than the drought of the 1930's. This storage volume remains as part of the Carryover Multiple Use Zone for this purpose.

7-03.1.5.2.6. **Gavins Point.** The Permanent Pool Zone at Gavins Point extends from 1160 to 1204.5 feet msl. The Annual Flood Control and Multiple Use Zone from 1204.5 to 1208 feet msl is the zone the project normally is regulated. The Exclusive Flood Control Zone from 1208 to 1210 is kept vacated except during flood control events. Gavins Point reservoir is normally regulated near 1206.0 feet msl in the spring and early summer with variations day to day due to rainfall runoff. The reservoir level is then increased to elevation 1207.5 feet msl following the nesting season for lake recreation enhancement.

7-03.2. **System Service Level.** To facilitate appropriate application of System multipurpose regulation criteria, a numeric "service level" has been adopted since the System was first filled in 1967. Quantitatively, this service level approximates the water volume necessary to achieve a normal 8-month navigation season with average downstream tributary flow contributions. For the "full-service" level, the numeric service level value is 35,000 cfs. For the "minimum-service" level, the numeric service level value is 29,000 cfs. This service level is used for selection of appropriate flow target values at previously established downstream control locations on the Missouri River. There are four flow target locations selected below Gavins Point to assure that the Missouri River has adequate water available for the entire downstream reach to achieve regulation objectives. Because of the fluvial nature of the bed of the Missouri River, flow targets are used rather than river stage targets at the control point locations. The discharge approach has resulted in a consistency in regulation over time as aggradation and degradation previously discussed has occurred at some of the System control point locations, which has changed river stage values for the same flow. The specific technical criteria for the relationship between service level and control point target discharge are as shown in Table VII-1. The service level determination has a range much greater than the minimum and full service discussed so far. The application of the service level concept is also used in the evacuation of flood runoff accumulated in the System by establishing service levels much greater than 35,000 cfs, as shown on Plate VI-1. The specific use of the service levels technique for System flood control evacuation is fully discussed in this chapter in Paragraph 7-04.13.4.

Table VII-1
Relation of Target Discharges to Service Level

Control Point Location	Flow Target Discharge Deviation from Service Level
Sioux City	-4,000 cfs
Omaha	-4,000 cfs
Nebraska City	+2,000 cfs
Kansas City	+6,000 cfs

7-03.2.1. **Service Level for Conservation and Normal System regulation.** A full-service level of 35,000 cfs results in target discharges of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Similarly, a "minimum service" level of 29,000 cfs results in target values of 6,000 cfs less than the full service levels at the four System control points identified above. Selection of the appropriate service level to be maintained is based on the actual volume of water-in-storage in the System. The use of actual water-in-storage means that forecasting is not relied upon when the volume of water in System storage is below normal.

7-03.2.1.1. **Service Level System Water-in-Storage Checks.** The System water-in-storage checks occur on constant key dates (March 15 and July 1) of each year. The volumes selected have been derived from long-range model simulations that allow the System to function to meet authorized purposes during significant multi-year drought periods. The specific technical criteria for System service level are as shown in Table VII-2. Straight-line interpolation defines intermediate service levels between full and minimum service. These service level determinations are for conservation and normal System regulation. During years when flood evacuation is required, the service level will be calculated monthly to facilitate a smooth transition in System release rather than a stepped approach at the March 15 and July 1 dates. Further details related to System regulation during flood events are provided later in this chapter.

Table VII-2
Relation of Service Level to the Volume of Water in System Storage

Date	**Service Level (cfs)**	**Water in System Storage (MAF)**
March 15	35,000 cfs (full-service)	54.5 or more
March 15	29,000 cfs (minimum-service)	49.0 to 31.0
March 15	(no service)	31.0 or less
July 1	35,000 cfs (full-service)	57.0 or more
July 1	29,000 cfs (minimum-service)	50.5 or less

7-03.3. **Non-navigation Years.** As shown in Table VII-2, the CWCP presented in this revised and updated Master Manual calls for suspension of navigation service if System water-in-storage is at or below 31 MAF on March 15 of any year. It should be noted that the occurrence of System storage at or below 31 MAF would most likely coincide with a national drought emergency. If any of the reservoir regulation studies performed for the development of the AOP indicate that System storage will be at or below 31 MAF by the upcoming March 15, the Corps of Engineers will notify the Secretary of the Army. Approval from the Secretary of the Army will be required prior to suspension of Missouri River navigation for the second of two consecutive years. The Corps will ensure that basin stakeholders are promptly informed of the notification to the Secretary of the Army and of the Secretary's decision regarding suspension of navigation.

7-03.4. **Season Length Determination.** The water-in-storage check for navigation season length is taken on July 1 of each year. Assuming System water-in-storage is above 31 MAF on March 15, a navigation season will be supported. If System water-in-storage is at or above 51.5 MAF, a full 8-month navigation season would be provided, unless the season is extended to evacuate System flood control storage. However, if System water-in-storage falls below 51.5 MAF on any July 1, a shortened navigation season would be provided to conserve water stored in the System to extend availability of water-in-storage in the case of an extended drought. The specific technical criteria for season length are shown in Table VII-3. Straight-line interpolation between 51.5 and 46.8 MAF of water-in-storage on July 1 provides the closure date for a season length between 8 and 7 months. If System water-in-storage on July 1 is between 46.8 and 41.0 MAF, a 7-month navigation season is provided. A straight-line interpolation is again used between 41.0 and 36.5 MAF, providing season lengths between 7 and 6 months. For System water-in-storage on July 1 below 36.5 MAF, a 6-month season is provided.

Table VII-3
Relation of System Storage to Season Length

Date	**System Storage (MAF)**	**Season Closure Date at Mouth of the Missouri River**
March 15	less than 31.0	no season
July 1	51.5 or more	December 1 – 8-month season
July 1	46.8 through 41.0	November 1 – 7-month season
July 1	36.5 or less	October 1 – 6-month season

7-03.4.1. **Season Opening and Closing Dates**. Navigation on the Missouri River is limited to the normal ice-free season, with a full-length flow support season of 8 months. Successful commercial navigation on the Missouri River from Sioux City to the mouth is dependent upon low-flow supplementation from the System, with occasional assistance from tributary reservoirs authorized to support Missouri River navigation. Navigation is limited to the ice-free season and, based on historical records of ice formation on the Missouri River together with experience gained in System regulation to date, the opening and closing dates of a normal 8-month navigation season have been scheduled as follows:

	Opening Date	**Closing Date**
Sioux City	March 23	November 22
Omaha	March 25	November 24
Kansas City	March 28	November 27
Mouth	April 1	December 1

In some years, ice conditions will undoubtedly delay the opening of the season and in others may force an early end to the season.

7-03.4.2. Fall extensions of the season beyond the normal 8-month length will normally be scheduled (ice conditions permitting) in years with above-normal water supply and when such extensions will not result in a drawdown into the System's Carryover Multiple Use Zone. Based on experience to date, these season extensions will normally be limited to 10 days beyond the normal closure date, resulting in a season closing on December 11 at the mouth of the Missouri River. In addition to enhancing navigation and water supply, the 10-day extension of the navigation season also enhances hydropower production by transferring an additional block of power from the normal navigation season to the more critical (for power purposes) winter season.

7-03.5. **System Seasonal Considerations.** For a portion of some years, deviations may be made from the above stated specific technical criteria to achieve the operational objectives of the CWCP or to comply with other statutory or regulatory obligations such as the ESA. In such circumstances, the AOP will explain the deviation from the specific technical criteria and the rationale for that deviation related to the operational objectives of the CWCP or applicable statutory and regulatory requirements. Other seasonal considerations and the corresponding reservoir regulation are further discussed elsewhere, as appropriate, in this Master Manual.

7-03.5.1. **System Winter Release Determination.** Another seasonal consideration is regulation in the wintertime period, which extends from December through March, to support the Congressionally authorized project purposes of hydropower production and downstream water supply and water quality. The specific technical criteria for Gavins Point Dam winter release rate is shown in Table VII-4. The System water-in-storage check for System winter release is taken on September 1 of each year.

Table VII-4
Relation of System Winter Release Level to System Storage

September 1 System Storage in MAF	**Average Winter Release from Gavins Point in cfs**
58.0 or more	17,000 cfs
55.0 or less	12,000 cfs

7-03.5.2. A modification to the winter release rate from Gavins Point Dam generally occurs when the evacuation of System flood control storage cannot be accomplished by providing a full-service navigation season with a 10-day extension of the navigation season. With an excess annual water supply, the winter season Gavins Point release will be scheduled at a rate of up to 25,000 cfs to continue to evacuate the remaining excess water in System flood control storage. When extremely high runoff has not been previously evacuated due to downstream flood control regulation, consideration will be given to scheduling winter releases in the 25,000 to 30,000 cfs range to accomplish the flood control objective of evacuating the Annual Carryover and Multiple Use Zone prior to the beginning of the next flood season.

7-03.6. **Integration of Downstream Requirements.** Gavins Point Dam releases are regulated to provide service to all multiple-use purposes, while at the same time recognizing the important flood control function of the System. In years of excess water supply, Gavins Point Dam releases in excess of full-service requirements may be necessary to evacuate flood control storage space. In recognition that these higher-than-normal releases can have an adverse effect on downstream floods, should unexpected rainfall occur, the higher releases should be made, to the extent possible, when floods from downstream tributaries are less likely. Also, the magnitude of these releases during the open-water season can be reduced somewhat by scheduling winter releases at a higher rate than would be the case with a normal water supply. While this may have the effect of slightly increasing the flood risk during the winter months, it reduces the flood risk during the open-water season when the flood potential is greatest. In addition, it may also increase the service provided to the power and navigation purposes by extending the navigation season length and increasing the amount of winter energy generation. Also, flood storage evacuation releases somewhat above full-service requirements during the open-water season usually have a beneficial effect upon navigation and hydropower production.

7-03.6.1. With a normal or less-than-normal water supply, navigation and hydropower releases during the open-water season are made taking into account the existing System water-in-storage and less-than-full-service flows may be provided when water-in-storage is low. Under such conditions, winter power releases may also be reduced. Table VII-4 shows that, for a normal System water-in-storage, a winter release from Gavins Point would be approximately 17,000 cfs. This release equates to fully serving the winter System hydropower production purpose and meeting all downstream water supply requirements. If, due to a depletion in System water-in-storage reserves down to the levels identified in Table VII-3, navigation season lengths need to be reduced to less than 8 months, winter releases from Gavins Point may be reduced to the minimum necessary for water intake or water quality requirements. The minimum flows considered applicable at this time are 9,000 cfs during the non-summer open-water season (March-April and September-November), 18,000 cfs during the summer open-water season (May-August) and 12,000 cfs during the winter period (December-February).

7-03.7. **System Conservation or Drought Reservoir Regulation Considerations**. As this manual was being revised, the System was experiencing its second extended drought since the System became fully operational in 1967. In fact, the amount of water in System storage was at the lowest level since it first filled. All authorized purposes, except for flood control, are affected negatively during extended drought. The impacts range from minor to very severe. Those most severely affected are recreation in the upper three large System reservoirs and below the System; navigation; intake access on the upper three large System reservoirs and in the river reaches between the reservoirs and downstream; cold water reservoir fishery species; reservoir and river water quality including thermal powerplants; irrigation; and hydropower production.

7-04. **System Regulation for Flood Control**. The regulation of the System for flood control is provided in the following paragraphs.

7-04.1. **Objectives of Flood Control Regulation.** The System is regulated, insofar as is practical, to prevent flows originating above or within the System from contributing to damaging flows through the downstream reaches of the Missouri River. Regulation of individual System projects is integrated to successfully meet this regulation objective. In addition, each individual System project is regulated to prevent, insofar as practicable, project releases from contributing to damaging flows through the downstream reaches in which that particular project affords a significant degree of control.

7-04.2. **Method of Flood Control Regulation.** In general, the developed method of regulation of the System as described in subsequent paragraphs may be classified as Method C, as defined in EM 1110-2-3600. This represents a combination of the maximum beneficial use of the available reservoir storage space during each flood event with regulation procedures based on the control of floods of approximate reservoir design magnitude. Specific procedures for the accomplishment of flood control regulation and examples are given in the succeeding paragraphs.

7-04.3. **Mainstem System Storage Space Available for Flood Control.** During any specific major flood event, all available storage space within the System will be used to the maximum extent practicable for flood control. This control will be provided in combination with other beneficial water uses for which the System was authorized. Approximately 16.3 MAF of System storage space are allocated for flood control purposes, of which 4.7 MAF are for this purpose exclusively; the remainder combines flood control with other authorized purposes. Most of the System flood control storage space is located in the Fort Peck (Fort Peck Lake), Garrison (Lake Sakakawea), Oahe (Lake Oahe), and Fort Randall (Lake Francis Case) projects. The flood storage in the Big Bend and Gavins Point projects is relatively minor in magnitude. In addition to allocated flood control storage space, surcharge space is available in each of the System reservoirs, primarily to ensure the safety of the project, but the use of that space will provide downstream flood reductions during extreme flood events. The Carryover Multiple Use Zone storage space, when evacuated, will also serve to benefit the flood control; however, deliberate evacuation of this zone to serve flood control will not be normally scheduled. As discussed in Appendix A of this manual, determination of the current flood control storage allocation of the System is based, to a large degree, on the vacated space required to control the 1881 flood. The 1881 flood is discussed in greater detail in Appendix A of this manual. The System flood control storage allocation has been examined and confirmed as adequate by numerous long-range regulation studies and the study for this Master Manual update.

7-04.4. **Amount of Tributary Reservoir Space Available for Flood Control.** The availability of upstream tributary reservoir flood control storage space was not recognized in the early flood studies. Early long-range System regulation studies also did not consider tributary reservoirs regulated specifically for flood control along the main stem of the Missouri River. Tributary reservoir storage space upstream from the System, if regulated for that purpose, can be effective in reducing flood crests in the lower Missouri River. Certain Missouri River basin tributary reservoirs, therefore, have a portion of their available storage space allocated to flood control use on a “replacement” basis. Replacement storage is defined as tributary reservoir storage space that is regulated in close coordination with the System and, as a consequence, can replace a portion of the System’s Annual Flood Control and Multiple Use Zone space. Replacement storage effectively allows for an increase in the amount of Carryover Multiple Use Zone storage that can be retained in the System projects. This greater amount of Carryover Multiple Use Zone storage results in increased multiple-use benefits while continuing the same degree of downstream flood protection that the System was designed to achieve. Past long-range regulation studies have incorporated this replacement storage concept and have demonstrated the resulting increased multiple-purpose benefits and continued flood control effectiveness of the expanded system of reservoirs. The use of replacement storage was last integrated into the System regulation in the 1980’s. Basin hydrologic conditions determine if use of tributary replacement storage is warranted.

7-04.4.1. **Replacement System Flood Control Storage Space.** Replacement flood control storage has been provided in three projects in the upstream basin: Clark Canyon, Canyon Ferry, and Tiber. These projects are all USBR projects controlling drainage areas upstream of Fort Peck. The Corps’ NWD Commander is responsible for the flood control regulation of these projects under Section 7 of the 1944 Flood Control Act. The NWD Commander has delegated the flood control regulation of these USBR projects to the Corps’ Omaha District Commander.

The drainage areas of these three projects all have relatively high runoff yields that produce significant volumes of the flood season runoff above the System. It is expected that, in years of large runoff that could conceivably tax the flood control abilities of the System, the replacement storage space in these projects would be used for the control of flooding on the Missouri River. The three USBR projects have the use of replacement System Flood Control Storage outlined in their respective tributary water control manuals. Each manual details the procedures for the Corps to follow in computing the amount of replacement storage available for each runoff season. When replacement storage for any or all of the projects is used, the actual regulation of the System proceeds as if this upstream tributary replacement storage space was a part of the System's Annual Flood Control and Multiple Use Zone. When replacement storage is used, the total System storage, or storage in a particular System project, could enter the flood season on March 1 above the base of the Annual Flood Control and Multiple Use Zone. This storage may appear to exceed the amount suggested by flood control objective criteria stated in this manual. Because the vacated space in the upstream reservoirs is being used as tributary replacement storage, what is initially seen as excess flood control storage in the System is actually consistent with criteria outlined in this manual. If replacement storage is used, the affected USBR tributary project(s) is credited with extra flood control benefits for a portion of System damages prevented on the Missouri River. The RCC is responsible for requesting, in writing, that the Omaha District Water Control Office initiate the process to use tributary replacement storage to benefit the System. The Omaha District in turn notifies the USBR that tributary replacement storage is being requested by the RCC. The USBR must then assure that the space is evacuated in the tributary project prior to flood season in accordance with the procedures written in the tributary manuals. The volume of replacement storage space available in the USBR tributary projects, as stated in the tributary project water control manuals, is shown in Table VII-5.

Table VII-5
System Replacement Flood Control Storage

Tributary Project		System Replacement Storage
Tiber		569,468 acre-feet
Clark Canyon		106,911 acre-feet
Canyon Ferry		450,000 acre-feet
	Total	1,126,379 acre-feet

7-04.4.2. **Other Tributary Reservoir Flood Control Storage Space.** In addition to the aforementioned USBR tributary projects that have assigned replacement flood control storage space, there are many other tributary reservoirs upstream from the System. Many of these tributary reservoirs have no Congressionally authorized flood control space or have flood control space assigned only for the purpose of local flood control in the immediate downstream river reach. At times, these reservoirs are drawn well below their normal full level prior to the flood season. Efficient Missouri River basin water resources management requires that the status of storage in all significant tributary reservoirs be considered and integrated into the overall regulation of the System, to the extent practical, while maintaining the overall flood control capability originally designed into the System.

7-04.5. **System Project Regulation Features.** Releases from individual System projects can be made through their respective powerplants, outlet works, and spillways. The powerplants will be used to the fullest extent possible to achieve the maximum benefit. During normal operating conditions, the greatest portion of project releases is made through the powerplants. When releases greater than the powerplant capacity or power demand are necessary, the outlet works and spillways will be used. The spillway, in combination with surcharge storage provided, ensures the safety of the dam in the case of extreme floods. Capacities of flow regulating devices at the System projects are indicated on rating curves represented on Plates II-5 through II-9 for Fort Peck, Plates II-20 through II-23 for Garrison, Plates II-34 through II-37 for Oahe, Plates II-47 through II-49 for Big Bend, Plates II-59 through II-62 for Fort Randall, and Plates II-72 through II-74 for Gavins Point. Additional information can be found in the individual System project water control manuals.

7-04.6. **System Flood Control Regulation.** Flood control regulation of the System projects, as per the objectives stated in Paragraph 7-04.1, is based on careful consideration of the following factors: river channel capacities downstream from individual System projects; observed and forecasted tributary flows to those portions of the Missouri River through which the System and individual System reservoirs afford a positive degree of flood control; observed and forecasted inflows into the System and the individual System reservoirs; amount of vacated individual System projects and total System storage space for controlling current and forecasted runoff; flood-producing potential of the drainage area both above and below the System and its relationship to individual System projects within the System; release requirements from the System and also from the individual System projects for purposes other than flood control; and available tributary reservoir flood control storage space above the System. The desired March 1 System water-in-storage is 57.1 MAF, equivalent to having each individual System reservoir at the base of its Annual Flood Control and Multiple Use Zone. When median or greater runoff occurs with System storage at 57.1 MAF or above on March 1, System releases are adjusted by computing the appropriate service level to draft storage to 57.1 MAF by March 1 of the following year. The three large reservoirs can either be balanced or unbalanced in terms of the amount of water in the Carryover Multiple Use Zone remaining on March 1 by specifying target storages; however the overall system goal is to have the system evacuated to the base of the Annual Flood Control and Multiple Use Zone (57.1 MAF) by March 1 each season to fully serve the flood control purpose.

7-04.6.1. **Use of Annual Flood Control Storage.** The flood control storage space in the System is normally evacuated prior to the start of the next flood season, which starts in March or early April. The Annual Flood Control and Multiple Use Zone will be allowed to fill or partially fill through the flood season, with the rate and amount of fill largely determined by actual and anticipated hydrologic conditions. Optimum System regulation requires the filling of a portion of this zone during the flood-runoff season to fully meet the regulation objectives of this CWCP. This is accomplished provided that inflows exceed the releases required to meet all authorized purposes.

7-04.6.2. **Use of Exclusive and Surcharge Flood Control Storage.** The Exclusive Flood Control Zone space provided in the System is reserved entirely for the control of floods and is not to be encroached on except for that specific purpose. Surcharge storage space is provided in addition to flood control space to assure project integrity and will be used only in the case of extreme floods.

7-04.7**. Individual System Project Flood Control Regulation.** Seasonal regulation of the storage within the individual System projects of the System will, to a degree, parallel that for the System, which is described in previous sections. The individual System projects have two zones designated for flood control, the Annual Flood Control and Multiple Use and the Exclusive Flood Control Zones. The Annual Flood Control and Multiple Use Zone is the zone where the projects normally operate under a wide range of runoff conditions. The zone designated as Exclusive Flood Control Zone is vacated most of the time and encroached upon only during significant runoff events. When the amount of water in an individual project or System storage is great enough to occupy this zone or the Corps' simulation models forecast the projects to rise into this zone, the projects are considered to be in a flood control state. Downstream runoff and streamflow conditions can also cause the System to be considered in a flood control state. The flood control state results in an increased frequency of forecasts and an examination of additional alternatives to return the System to a normal condition. During a flood control state, the flood control purpose is considered foremost in making release determinations.

7-04.7.1. **Fort Peck and Garrison Flood Control Considerations.** The winter season is the time period when the firm power demand from the System is the greatest. To enhance winter energy generation, winter releases from the upstream Fort Peck and Garrison reservoirs are often maintained at the maximum level possible that is consistent with downstream channel capacity. During the winter, channel capacity is reduced because of threat of flooding during river ice formation or when an established Missouri River ice cover raises Missouri River stages. Because of the somewhat unpredictable behavior of a downstream ice cover, the exact potential volume of winter releases from these upstream projects cannot be estimated accurately. Pre-winter System reservoir storage levels are scheduled on the basis that the established winter release rate will be made most of the time through these upstream powerplants. If channel conditions during the winter are such that the established winter release rate assumed in pre-winter scheduling is not possible, a release deviation will be implemented. The changed release rate may result in some imbalance in the amount of water-in-storage in individual System reservoirs by the following spring. This storage imbalance will favor the downstream flood control purpose, with additional evacuated storage space located in Oahe the farthest downstream of the three largest System projects. This is not a matter of great concern because open-water channel capacities below Fort Peck and Garrison are sufficient to allow a relatively fast restoration of System storage balance following the ice breakup if attaining a balance in the amount of water-in-storage at the large three reservoirs is still a goal at that time of the season.

7-04.7.2. **Fort Randall Flood Control Considerations.** The early spring flood potential is defined by the amount of accumulation of plains snow and the ground conditions in the incremental areas above and between the System reservoirs. Manipulation of the Fort Randall reservoir level prior to the flood season is based on the spring flood potential. In years when the early-spring flood potential between Oahe and Fort Randall is high because of plains snow accumulation or the flooding potential below Fort Randall is high, the Fort Randall reservoir level may be held below its base of the Annual Flood Control and Multiple Use Zone prior to the onset of spring runoff. This reservoir level manipulation is achieved by reducing late winter power releases from the Oahe and Big Bend projects. The additional vacated storage space in

Fort Randall allows for the capture of flood flows with a less severe disruption of power releases from upstream projects through the spring runoff period. During normal runoff situations, the reservoir will be maintained at the base of flood control, 1350 feet msl. During those years that the flood potential below Oahe is low, it may be desirable to raise Fort Randall reservoir level above the base of the Annual Flood Control and Multiple Use Zone prior to March 1. This allows for an increased amount of energy to be generated during the high demand winter period. Additionally, the higher reservoir level provides a reserve of additional water that may be used to satisfy short-term demands for increased System releases during the following navigation season for downstream flow support. Experience has indicated that a Fort Randall reservoir level of about 1355 feet msl, 5 feet above the base of the Annual Flood Control and Multiple Use Zone, is satisfactory for meeting the short-term downstream flow support demands. Experience has also indicated that maintaining a minimum pool elevation of 1353.0 feet msl will meet the recreational and irrigation purposes during the April to September timeframe. Consequently, any deliberate fill of the Fort Randall reservoir, based on low flood potential prior to March 1, will normally be limited to an elevation of 1355.0 feet msl.

7-04.7.3. **Gavins Point Flood Control Considerations.** Consideration of the early spring flood potential in the drainage area between Fort Randall Dam and Gavins Point Dam is similar to that outlined in Paragraph 7-04.7.2 for the area between the Oahe and Fort Randall projects. Because it is possible to manipulate the Gavins Point reservoir level in a relatively short period of time, the reservoir level at the start of the flood season will be somewhat dependent on this spring flood potential. When the spring flood potential between Fort Randall Dam and Gavins Point Dam is high, the Gavins Point reservoir level will be drawn down well below the base of Annual Flood Control and Multiple Use Zone immediately prior to the start of the snowmelt period and allowed to refill from the snowmelt runoff. The limit of this drawdown will be dependent on the potential for flooding based on the forecasted runoff in the Fort Randall Dam to Gavins Point Dam reach. When the runoff potential between Fort Randall and Gavins Point Dam is very low, as evidenced by the lack of a plains snow cover or by a lack of antecedent rainfall over the incremental drainage area, complete evacuation of the Annual Flood Control and Multiple Use Zone may not be necessary. Continued surveillance of the runoff potential in this incremental area is required. If the runoff potential increases during the March through July flood season, appropriate measures will be taken to lower the level of the Gavins Point reservoir to near the base of the Annual Flood Control and Multiple Use Zone, which is 1204.5 feet msl; however, consideration of the state of tern and plover nesting must be made prior to lowering the reservoir. The potential effects on the recreational use of the Gavins Point project will be a consideration in any decision made to reduce the elevation of Gavins Point to capture additional runoff. In this area, there is continued pressure from recreation specific interests to maintain Gavins Point reservoir levels at the highest practical level consistent with the flood runoff potential. Additionally, keeping the Gavins Point reservoir level high, along with a corresponding storage decrease in upstream reservoirs, increases System power production because the small size of Gavins Point provides a greater amount of power per unit of storage than any of the other System projects. Because releases from this downstream project are normally greater than from other System projects, the additional head is more effective for increased energy production than a corresponding head increase at another System project. The Gavins Point reservoir level following the March through July flood season and the completion of tern and plover nesting season will normally be maintained at 1207.5 feet msl to enhance both recreation and power. The base of the Exclusive Flood Control Zone is 1208.0 feet msl. Manipulation of the Gavins

Point and Fort Randall reservoir levels, as described in this and the preceding sections, has no effect on the overall availability of evacuated flood control storage space in the System prior to early spring floods. This is because desired reservoir levels are realized by scheduling releases from upstream projects. Downstream System release rates are also not affected by any System reservoir level manipulations discussed in the subparagraphs of 7-04.7.

7-04.8**. System Flood Control Regulation Criteria.** In order to conduct System flood control regulation in an optimum manner, while at the same time providing the maximum possible service to the other multiple-use purposes of the System, storage space allocated for flood control in the downstream System reservoirs of Big Bend, Fort Randall, and Gavins Point should be maintained as near to the base of their Annual Flood Control and Multiple Use Zones as possible, which is consistent with the discussion in Paragraph 7-04.7. The basis for this type of System regulation is explained in the following subparagraphs.

7-04.8.1. Vacant space in the three smaller downstream System projects provides an additional measure of flood control for the large urban damage centers below the System than the same amount of vacated space in the upper three larger System projects.

7-04.8.2. When the levels of the Big Bend and Fort Randall reservoirs are near the base of their respective Annual Flood Control and Multiple Use Zones, tailwater levels at the immediately upstream Oahe and Big Bend projects will provide maximum power heads. This will result in improved hydropower production.

7-04.8.3. In the case of heavy runoff originating below the System, vacant Annual Flood Control and Multiple Use Zone space in the downstream three smaller System projects helps both flood control and power generation. These smaller projects then have the space to store the upstream project releases necessary to maintain the optimum System power generation from the upstream three larger System projects, while releases can be reduced from the smaller downstream projects to provide the maximum practical flood reductions.

7-04.8.4. Flood control releases from the System will be made in such a manner as to satisfy the following general requirement. When allocated flood control storage space in Fort Randall is available to capture existing or forecasted flood events, maximum System releases will normally be limited to a rate that will not contribute to flows that exceed 120,000 cfs at Sioux City, Iowa. If insufficient storage is available in Fort Randall reservoir for controlling the existing or forecasted runoff, System releases will be increased as necessary to ensure project safety while at the same time providing significant downstream flood reductions.

7-04.9. **System Regulation Considerations During Winter Ice Season.** The maximum flow that may be passed without damage varies through the length of the Missouri River and is dependent on channel dimensions, the degree of encroachment onto the floodplain, and improvements such as levees and channel modifications. Capacities at specific locations also vary from season to season, especially in the middle and upper river reaches, where a decrease in capacity due to the formation of an ice cover is common through the winter and early spring months. Like with most streams, the capacity of the Missouri River channel usually increases progressively downstream, although instances occur where this trend is reversed.

7-04.9.1. Above Sioux City, the Missouri River and its tributaries can be expected to freeze over each year. An intermittent ice cover will also usually form on the Missouri River as far downstream as St. Joseph. In the downstream reaches of the river below St. Joseph, an ice cover may occasionally form as a result of severe and extended cold temperatures. The time of formation and breakup of the ice cover varies widely from year to year, but an ice cover may be expected over some reaches from early December to about mid-March. RCC Technical Report No. SS-N-71, “Missouri River Freeze and Breakup,” November 1971, presents detailed historical data on this subject.

7-04.9.2. An ice cover greatly decreases the river conveyance at any given stage and, consequently, the channel capacities are significantly reduced. The formation and breakup of the ice cover through any reach or series of reaches often causes ice jams. Substantial volumes of water are stored temporarily by these ice jams or by a solid ice cover due to flow restriction by the ice. This phenomenon has a marked effect upon streamflow and river stages. Downstream flows and accompanying stages may be markedly reduced at the onset of the jam, while stages just upstream or in the upstream portions of ice-covered sections of the river may rise to damaging levels. The volume of ice in any particular reach of the river that may contribute to jamming is a function of the thickness of ice, the width of the river, and the length of the reach. With low stages, the river width, and the ice volume within the reach are reduced from what they would have been with higher stages. Most of the maximum stages of record in the upper Missouri River resulted from ice jams and occurred prior to regulation provided by the System. The System projects tend to act as a trap to flowing ice and reduce the possibility of severe ice jam formation in downstream areas, both during the period of ice formation and ice breakup.

7-04.9.3. In the downstream portions of the Missouri River, ice jamming or ice bridging is likely to occur during periods of extremely cold weather. Large cakes of ice form and float downstream to a restricted reach where they lodge. The resulting blockages are fed by additional floating ice. Usually, such blockages in the downstream reaches are temporary in nature and continue until such time that temperatures moderate. On several occasions, blockages have formed in the Nebraska City to St. Joseph reach of the Missouri River and have caused stages to exceed established flood stage, in spite of low releases from Gavins Point. In recent years, the Missouri River normally freezes first below Gavins Point Dam in the Ponca area above Sioux City; below Decatur, Nebraska; below Fort Calhoun, Nebraska; below the Platte River confluence with the Missouri River and near Leavenworth, Kansas. During severely cold Midwest winters, over 400 miles of the Missouri River have been covered by ice below Gavins Point Dam. Generally, the long travel times to most locations prevent the Corps from making significant changes in Gavins Point releases to correct stage fluctuations from ice jam events below the System.

7-04.9.4. Ice cover forming on the Missouri River below Fort Peck, Garrison, and Oahe Dams has a marked effect on the winter regulation of these projects. At the time the ice cover first forms below Fort Peck and Garrison Dams, the downstream channel capacities are at a minimum. As the river ice cover stabilizes, flows are normally slowly increased followed by a progressive increase in the channel capacity that continues until just prior to the end of the winter season. It is often possible to increase releases while maintaining relatively constant downstream stages. This phenomenon is discussed in more detail in two RCC Technical Reports, “Freezing of the Missouri River Below Garrison Dam,” February 1973, and “Freezing of the Missouri River Below Fort Peck Dam,” July 1973.

7-04.9.5. Ice cover forming on the Missouri River below the Oahe Dam also has a marked effect upon the winter regulation of this project. As discussed previously, Federal funds are currently being used to acquire the properties most susceptible to ice-affected flooding in Pierre and Fort Pierre, South Dakota.

7-04.9.6. **System Winter Season Flood Control Releases.** Due to restricted channel capacities under ice conditions, releases from specific projects during the winter river ice-cover period will be limited at all six System projects.

7-04.9.6.1. **Fort Peck.** At the time when active downstream river ice formation is anticipated or occurring in the reach between Fort Peck Dam and the mouth of the Yellowstone River, mean daily releases from Fort Peck are limited to a maximum of 10,000 cfs unless higher releases are needed for flood control evacuation. After a river ice-cover has formed, releases will be limited to prevent Missouri River stages from exceeding 11 feet at Wolf Point or 13 feet at Culbertson unless higher release rates are required for flood control evacuation. Experience indicates that, after the downstream ice cover has formed and stabilized, mean daily releases can be increased up to 15,000 cfs, which is the Fort Peck powerplant capacity. However, increases in releases from the normal freeze-in level to the maximum winter ice-covered level should normally be made in gradual increments. Additionally, tributary runoff between Fort Peck and the downstream Wolf Point and Culbertson gages due to plains snowmelt prior to the time the river becomes ice-free are a consideration in release scheduling.

7-04.9.6.2. **Garrison.** Garrison releases are normally not scheduled above 20,000 cfs in December to prevent the river at the Bismarck gage from exceeding a 13-foot stage during the winter freeze-in period. Releases have been reduced to as low as 16,000 cfs in past years as the head of ice advanced upstream from the upper end of Lake Oahe. This action is taken to prevent flooding of housing developments adjacent to the river in Bismarck and Mandan, North Dakota. Releases can be safely increased without increasing the river stage after an ice cover is established. After the river ice cover has stabilized in the downstream Missouri River reach around Bismarck, releases from Garrison can be gradually increased without increasing the river stage. Experience has shown that approximately 1 month after the initial freeze-in at Bismarck, releases approaching 27,000 cfs are possible. Tributary runoff between Garrison Dam and Bismarck prior to the time the Missouri River becomes ice-free must be considered in scheduling Garrison releases. The 27,000 cfs winter release rate is a reduction from the original Garrison powerplant capacity winter release rate of 35,000 cfs. This reduction is attributed to aggradation in the upper end of Oahe, which has caused a reduction in channel capacity.

7-04.9.6.3. **Oahe.** Experience has indicated that the normal powerplant peaking at Oahe maintains the 7-mile reach between Oahe Dam and the head of Lake Sharpe largely in an ice-free condition under all but the most severe weather conditions. Therefore, the channel capacity available requires no restrictions on winter discharges through the Oahe powerplant except during the most severely cold conditions. Several times since 1979, minimum and maximum restrictions have been placed on Oahe generation when extremely cold weather results in ice formation and high stages in the Pierre and Fort Pierre area. The formation of this ice cover at times has resulted in street flooding. The Bad River delta, which has raised the water surface for both open-water and ice-affected flows, exacerbates this problem. As a result, powerplant release restrictions have been imposed during critically cold periods. The previously discussed Corps project will reduce flood damage potential, which will allow for some reduction in these restrictions.

7-04.9.6.4. **Big Bend.** Big Bend discharges directly into Lake Francis Case, consequently, no restrictions on winter releases are necessary.

7-04.9.6.5. **Fort Randall.** Although the ice-covered Missouri River channel between Fort Randall Dam and the head of Lewis and Clark Lake could sustain higher discharges without resulting in damages, the average winter season release from Fort Randall is normally limited to about 15,000 cfs. This release restriction is due to the restricted ice-covered channel capacity below Gavins Point Dam combined with the small amount of storage space available in Gavins Point reservoir to re-regulate flows in this downstream project. Additionally, System regulation associated with an average winter release of 15,000 cfs from Fort Randall represents full winter service to the power function of the System. Winter release rates when the channel is ice-covered may be increased gradually to average 25,000 cfs or slightly more when it is deemed necessary to evacuate accumulated flood storage.

7-04.9.6.6. **Gavins Point.** In the reach of the Missouri River from Gavins Point Dam to Kansas City, Missouri, ice jams can and have caused flood damage. This reach is particularly vulnerable due to intermittent freeze-ups and breakups of Missouri River ice cover throughout the winter. This reach of the river valley is also highly developed relative to the rest of the basin; therefore, there is a high flood damage potential related to serious ice jams. There has been ice-jam-related flooding during extremely cold winters when much of the Missouri River below the System is ice-covered. The long travel time to this reach of the river makes river-icing problems particularly difficult, if not impossible, to resolve with System release changes. Normally, any attempt to modify the result of the river icing this far downstream, results in a risk to upstream ice cover and potential flooding. Experience has demonstrated that the icing situation normally resolves itself before the System release change arrives at the problem location. The travel times during open water periods are 5 to 10 days to this reach, and when ice cover is present, these times are extended considerably. Additional degradation of the Missouri River in the Sioux City vicinity has permitted the maximum Gavins Point winter release rate to be increased from 20,000 cfs up to 30,000 cfs. Open water stages corresponding to a release of 30,000 cfs today are essentially the same as they were previously with a 20,000 cfs release. At times, reductions below the 25,000 cfs level may be necessary due to the formation of severe ice blockages in the Gavins Point to Sioux City reach.

7-04.9.6.6.1. During any non-navigation time period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the System dams, to the extent reasonably possible. During periods of extended drought, recent experience indicates an average winter release of 12,000 cfs with increases up to 18,000 cfs during river ice formation periods is required to meet winter water supply needs downstream of Gavins Point Dam extending as far as the Kansas City metropolitan area. When the System was first filled, the downstream reach of concern during the winter was much shorter, mostly confined to the Missouri River reach from Gavins Point Dam to Omaha, Nebraska. Additional years of degradation have, however, resulted in moving the most affected area downstream to at least Kansas City. It should be noted that most of these winter water supply problems are related to intake access problems that need to be corrected by the intake owners; however, a large number of problem areas may be an indication that it is more than just an access problem. The Corps updates a Missouri River Stage Trends Report each year that discusses the degradation and aggradation that is occurring on the Missouri River. The report shows graphically the effects of degradation or aggradation during the past several years for specific Missouri River locations at various levels of flow. Some intake owners have used this report in planning for adequate water supply access.

7-04.10. **System Flood Control Considerations During the Open-Water Season.** Maximum releases during the open-water season are based on downstream channel capacities at all times that flood control storage space is available to control existing or forecasted inflows.

7-04.10.1. **Use of Upper Three Reservoirs.** To the extent reasonably possible, the available flood control storage space available in the three upper System reservoirs, Fort Peck, Garrison, and Oahe, will be used for the control of floods in preference to the flood control storage space available in the three lower System reservoirs. The allocated flood control space in the downstream Big Bend, Fort Randall, and Gavins Point projects will be used to the degree necessary to re-regulate upstream System reservoir releases and to control runoff originating below the Oahe Dam drainage area.

7.04.10.2. **Balancing Available Flood Control Space.** To the extent reasonably possible, a balance of the vacant storage space (in terms of percent of allocated space) within both the Annual Flood Control and Multiple Use Zones and Exclusive Flood Control Zones will be maintained between the three larger upper; Fort Peck, Garrison, and Oahe projects when the flood control storage in the System is taxed or expected to be taxed by forecasted inflows. When flood control storage zones are more than able to contain forecasted inflows, departures from storage balance criteria will be permitted in the interest of enhancing other Congressionally authorized purposes. It should be recognized that, in the event of extreme deviations in expected runoff at individual System projects, some time will be required to achieve a storage balance in the upper three reservoirs without causing downstream damaging flows.

7-04.10.3. **System Flood Control Evacuation Priority.** Evacuation of System flood control storage immediately following the capture of flood runoff will be accomplished, insofar as practical, on the basis of established priorities in the order as follows:

1st Surcharge Storage from all of the System reservoirs.

2nd Exclusive Flood Control Storage Zones in the three lower reservoirs (Big Bend, Fort Randall and Gavins Point).

3rd Exclusive Flood Control Storage Zones in the three upper larger reservoirs (Fort Peck, Garrison, and Oahe).

4th Annual Flood Control and Multiple Use Zone in Gavins Point and in Fort Randall above elevation 1360.0 feet msl. Evacuation of Fort Randall storage below elevation 1360.0 feet msl is greatly influenced by power loads and the required power generation at Oahe and Big Bend.

5th Annual Flood Control and Multiple Use Zones in the three upper projects (Fort Peck, Garrison, and Oahe). In general, evacuation of at least the upper portions of the Annual Flood Control and Multiple Use Zones in the three upper reservoirs should be conducted in such a manner as to maintain a balance of available allocated space within all three of the large reservoirs. Due to the restricted channel capacity below Fort Peck, it may be necessary, depending on conditions, to distort this balance to assure the evacuation of that System project.

6th Evacuation of the Annual Flood Control and Multiple Use Zone storage space will be made in a manner that, to the extent reasonably possible, will assure complete evacuation of this space prior to the beginning of the next flood runoff season while achieving the maximum beneficial conservation use of the stored water based on the operational objectives stated in this manual. The serious hazard of downstream flood damages in the case of late fall or winter ice conditions may make complete evacuation of Annual Flood Control and Multiple Use Zone prior to the next flood season inadvisable. In certain extreme high water years, there is a lesser risk associated with leaving some water in the Annual Flood Control and Multiple Use Zones as opposed to continuing the evacuation and possibly contributing to downstream flood damages during the late fall and winter months. Even in these high water years, a major portion of the Annual Flood Control and Multiple Use Zone will be evacuated prior to the next runoff season.

7-04.11. **Scheduling of System Releases.** The flood control purpose of the System continues to be a major consideration in scheduling System releases, irrespective of the amount of water contained in the System or the character of inflows to the System. Multipurpose regulation techniques described in this Master Manual are consistent with the flood control objectives. During the winter months, multipurpose releases are restricted due to the possibility of ice formation and consequent severe loss of channel capacity. Downstream flow support releases during the open-water season are based on maintaining specified target flows at downstream control points. This type of multipurpose regulation serves flood control and the other downstream purposes most of the time.

7-04.11.1. There are times, however, when the service provided to other purposes must be modified in the interest of the flood control objective. During winter months, severe ice jams can form on the Missouri River below Gavins Point Dam, even with the restrictions to System releases that are imposed during the winter season. Because this is the non-crop season, flood damages associated with the resultant high Missouri River stages are, fortunately, usually much less than would occur if similar stages were experienced during the summer season. Particularly severe ice jamming could result in flooding of property susceptible to flood damage; therefore, when severe ice jamming is occurring at downstream locations, a reduction in System releases may be warranted. While past experience indicates that those release reductions will have very little effect on stages associated with the jams, action by the Corps will indicate awareness of the problem and the desire to alleviate the adverse conditions. Such release reductions will usually be only temporary, extending at the most, for a week or two. The overall level of service to other System purposes can usually be maintained by increasing releases after the river ice cover stabilizes. At other times, it is prudent to increase System releases prior to the onset of expected river ice buildup or even during a significant ice jam. Experience during recent years indicates that increasing System releases speeds the recovery of the Missouri River to more normal stages and assures that the downstream water intakes are operational sooner or affected less by the icing condition. The Corps will evaluate each ice-jam situation on a case-by-case basis and make a determination regarding the appropriate release.

7-04.12. **System Service Level.** Because the ability to evacuate System storage is severely restricted during the winter months, the necessary increases in System release rates for storage evacuation purposes above the rates necessary for navigation and other authorized purposes will largely be made during the navigation season. The methodology to determine releases to evacuate flood storage and reduced System releases during periods of downstream flood events is an extension of the "service level" and "target flow" concepts described in Paragraphs 7-03.2 through 7-03.2.1.1 of this chapter. Basic to the use of the "service level" concept is a definition of the minimum and maximum service levels that can be maintained while meeting the other regulation objectives.

7-04.12.1. **Flood Control Considerations for the System Minimum Service Level.** As discussed earlier in this chapter, the minimum open-water level that will sustain the navigation purpose throughout the Missouri River navigation project is the 29,000 cfs service level. Target flows for this service level are 25,000 (29,000 - 4,000) cfs at Sioux City, Iowa and Omaha, Nebraska, 31,000 (29,000 + 2,000) cfs at Nebraska City, Nebraska and 35,000 (29,000 + 6,000) cfs at Kansas City, Missouri. Making release reductions below this service level for flood control purposes could have serious adverse effects on navigation, downstream recreation, and water supply. Adverse effects on power production are also quite probable with sharply reduced System releases. Release reductions to below the minimum navigation service level should, therefore, be made only when it is reasonably assured that the reductions will be of significant benefit from the flood control standpoint. Reductions below the minimum service level will not be made without consideration of the effects on other project purposes.

7-04.12.2. **Flood Control Considerations for the System Full-Service Level.** The full-service level of downstream open-water flows is 35,000 cfs. This is the flow necessary to meet the navigation channel requirements along with all other Congressionally authorized project purposes, such as water supply and recreation, served below the System. Missouri River target flows for this service level are 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City and 41,000 cfs at Kansas City. Navigation and some other authorized purposes are enhanced to some extent by flows in excess of those provided by this full-service level. Powerplant capacities of the downstream powerplants are also generally sufficient to use System release rates somewhat in excess of those necessary for full-service flows. Any enhancement to navigation and power production would be negligible for service levels increased beyond the 45,000 cfs service level. System releases above 45,000 cfs may, however, be necessary for flood storage evacuation purposes.

7-04.12.2.1. During the winter season, a 5,000 cfs or higher release level from Fort Randall Dam can be sustained during all past hydrologic conditions since 1898 with the present level of water resource development. Reductions below this level will not be made. The full-service winter level corresponds to a 15,000 cfs average winter release from Fort Randall Dam. Past experience has indicated that the winter release level can be increased to 25,000 cfs from Gavins Point Dam with only a modest increase in the potential for downstream ice-jam flooding. This increased potential is held to a minimum by selective release scheduling through the winter season, based on temperature forecasts and observations of current or forecasted ice conditions. In high runoff years when complete evacuation of the accumulated flood control storage during an extended navigation season would result in release rates that are substantially above normal, consideration will be given to scheduling winter System releases in the 25,000 to 30,000 cfs range to provide the most effective overall System flood control regulation.

7-04.13. **System Service Level Selection for Flood Control Evacuation.** Selection of the appropriate service level for flood storage evacuation purposes in excess of the full-service level is dependent on anticipated runoff from the Missouri River drainage area above the System; depletions to this runoff that can be expected to occur prior to the time this runoff appears as inflows to the System reservoirs; current storage conditions in the System and in the major tributary reservoirs located above the System; and evaporation from the System reservoirs. Plate VI-1 was developed to determine the service level at any time during the year. This plate relates the annual water supply and time of year to the appropriate System service level. If a significant growth in depletions occurs, appropriate revisions should be made to Plate VI-1. The revisions would be necessary because the water supply necessary to maintain the indicated service level is based on depletions expected. Determination of water supply is made based on a combination of (a) forecasted runoff above Gavins Point Dam from the current date through December, (b) current amount of water in System storage, and (c) the tributary reservoir storage deficiency.

7-04.13.1. **Forecasted Runoff.** The forecasted runoff for the remainder of the current calendar year is developed by procedures described in Paragraph 6-04.1.1 of this Master Manual, with specific forecast techniques described in detail in MRD-RCC Technical Study MH-73.

7-04.13.2. **Tributary Storage Deficiency.** The current tributary water-in-storage deficiency is developed by first accumulating the current reservoir water-in-storage in each of the 10 tributary USBR reservoirs listed in Table VII-6. All of these reservoirs are located above the System. These reservoirs, when filled to levels that can be expected during years of excess runoff, have a storage capacity of over 6 MAF. For the purpose of determining an appropriate System service level, a 5.5 MAF level of tributary reservoir storage was selected as the base level for computation of an acceptable water-in-storage level condition by March 1 of the next year. If there is currently more water than 5.5 MAF, the difference is subtracted from the water supply value computed for use in Plate VI-1, and vice versa, as a second step in the computation.

Table VII-6
USBR Projects Used for Calculating Tributary Storage Deficiency for the Water Supply Computation

Lima	Tiber
Clark Canyon	Bull Lake
Hebgen	Boysen
Canyon Ferry	Buffalo Bill
Gibson	Yellowtail

7-04.13.3. **Future Adjustments to Service Level.** It can be expected that future adjustments to Plate VI-1 may be required. Several factors and past history indicate that changes in tributary reservoir storage and in System storage due to sedimentation and other factors may require some adjustment when they become significant. Also significant Missouri River basin depletion changes may require adjustment. A significant change in release patterns for any reason may require the information provided on Plate VI-1 to be adjusted since it assumes a steady flow will be provided throughout the remainder of the period.

7-04.13.4. **Determining the Service Level for Flood Control Evacuation.** Plate VI-1 presents water supply (System water-in-storage plus anticipated runoff into the System for the remainder of the year) evacuation curves. Releases based on the curves can be expected to result in the evacuation of the System to the base of the Annual Flood Control and Multiple Use Zone, provided scheduled winter releases can also be maintained, by the following March 1. Determination of the appropriate service level is accomplished by computing the current tributary reservoir water-in-storage excess or deficiency and adding or subtracting it from the current actual System water-in-storage. The resulting water-in-storage is then added to the forecasted remaining calendar year runoff into the System to obtain the current water supply value. The water supply value, which is computed as described above, is then used to enter Plate VI-1. By following the water supply value horizontally to the current date, the appropriate service level on which System releases should be based is determined. Forecasted runoff is an essential (Plate VI-7 shows an example of the calendar year forecast) component in determining the service level. Because forecasts of future runoff (which may not materialize) are basic to the use of this plate, and because the potential for downstream tributary flood runoff is greater during the spring and early summer months, the service level provided should not be increased above the 35,000 cfs, full-service level prior to July 1 unless an indicated service level of 40,000 cfs or greater is identified by using Plate VI-1. This limitation provides a factor of safety in favor of the flood control purpose. For service level determinations below full-service, release rates are computed based on actual water-in-storage checks discussed in this chapter and on Plate VI-1. The March 1 date indicators on the curves are consistent with the service level definitions defined in this chapter.

7-04.14. **System Expanded Full-Service Level.** The 35,000 cfs service level is considered to be the full-service level for meeting all authorized purposes of the System. The initial increase above this full-service level has been designated as the “expanded full-service level” and consists of extending the navigation season 10 days beyond its normal closing data of December 1 at the mouth of the Missouri River. Additionally, as a storage evacuation measure, winter releases averaging 20,000 cfs will be scheduled from Gavins Point Dam. While a primary purpose of this expanded full-service is for the evacuation of storage space in the System, it also benefits the other authorized purposes. An additional 10 days of navigation service also results in the transfer of a substantial block of power from the normal fall navigation season, when power is relatively abundant, to the winter season. In some years, ice conditions may preclude this extension, and if such occurs, it may be necessary to carry a minor amount of excess water over to the succeeding flood season. In recognition of ice problems that may occur, releases during the 10-day extension of the navigation season will be made at the full-service level unless storage evacuation requirements are such that higher releases are deemed necessary. The announcement of this expanded service should be made as soon as it is determined to allow the downstream users to take full advantage of the 10 days of higher flows.

7-04.15. **System Reservoir System – Missouri River Flood Target Flows.** Normally, the difference between the selected service level and target flows at control points below the System will be the same for evacuation of flood storage as for normal navigation or downstream flow support releases. This results in Missouri River flow targets located at Sioux City and Omaha of 4,000 cfs less than the current service level, at Nebraska City of 2,000 cfs greater than the current service level, and at Kansas City of 6,000 cfs greater than the current service level. Similar to navigation or downstream flow support targets, storage evacuation targets are for minimum flows at the controlling flow target location. For example, with a 40,000 cfs service level, a target flow of 42,000 cfs at Nebraska City might be controlling with Sioux City, Omaha, and Kansas City forecasted flows in excess of their respective targets of 36,000, 36,000, and 46,000 cfs, respectively. When target flows at the non-controlling locations approach critical levels from a flood damage standpoint, the service level-target flow concept is modified to emphasize System regulation for downstream flood control instead of navigation support or System storage evacuation.

7-04.16. **Missouri River Flood Target Flows – Full-Service Provided.** As a flood control measure, the normal relationship between service levels and target flow levels may be modified when large amounts of tributary inflow are forecasted between Gavins Point Dam and the downstream flow target control points. Criteria for these modifications are presented in Table VII-7. For example, if the current service level were 40,000 cfs, System releases would be reduced consistent with the full-service level if it were deemed necessary to maintain flows at or below 46,000 cfs at Omaha, 52,000 cfs at Nebraska City, or 76,000 cfs at Kansas City. These target flows may be modified by up to 5,000 cfs after consideration is given to antecedent, current, and projected hydrometeorological conditions. Modification of target flows to the full-service levels provides a safety margin for the inability to accurately forecast downstream tributary runoff and from unexpected rainfall. There are, however, conditions during large runoff years similar to 1997, when the above criteria must be replaced with a System regulation approach that will result in the best flood control for the lower river. Repeated reductions in System releases early in the runoff season will likely result in the need to make higher System releases to evacuate accumulated floodwater later in the season. The progressive increase in System releases must be evaluated against the approach of taking some small flood risk over a longer period of time and providing a slightly higher System release initially.

Table VII-7
Criteria for Modifying Target Flows – Full Service

Target flows will be reduced to those consistent with the full-service level of 35,000 cfs when one or more of the anticipated downstream flows exceed the current service level flow values by more than:	
6,000 cfs at Omaha	(target flow plus 10,000 cfs)
12,000 cfs at Nebraska City	(target flow plus 10,000 cfs)
36,000 cfs at Kansas City	(target flow plus 30,000 cfs)

7-04.17. **Missouri River Flood Target Flows – Minimum Service Provided.** As an additional flood control measure for the lower Missouri River, the normal relationship between minimum service levels and target flow levels will be modified when large amounts of tributary runoff are forecasted or occurring between Gavins Point Dam and the downstream flow target control points. Selected criteria for these modifications are noted in Table VII-8. These target flows may also be modified by up to 5,000 cfs after consideration is given to antecedent, current, and projected hydrometeorological conditions. Modification of target flows to the minimum service levels provides even a greater safety margin (than to the full-service level) for the inability to accurately forecast downstream tributary runoff and from unexpected rainfall. There are, however, conditions during large runoff years similar to 1997, when the above criteria must sometimes be replaced with a System reservoir regulation approach that will result in the best flood control for the downstream reach for the entire flood runoff season. Repeated reductions in System releases early in the runoff season will result in the need, later in the season, to make higher System releases to evacuate accumulated floodwater. The progressive increase in System releases must be evaluated against the approach of taking some small flood risk over a longer period of time. This System flood control approach is accomplished by providing a slightly higher System release initially or earlier in the flood runoff season; therefore, lower flows are provided later in the year. This flood control reservoir regulation approach is at times the preferred option when it is known the flood runoff season will be extended because a large volume of runoff is expected.

Table VII-8
Criteria for Modifying Target Flows – Minimum Service

Target flows will be reduced to those consistent with the minimum-service level of 29,000 cfs in order that one or more of the anticipated resultant downstream flows exceed the current service level flow value by more than:	
11,000 cfs at Omaha	(target flow plus 15,000 cfs)
22,000 cfs at Nebraska City	(target flow plus 20,000 cfs)
66,000 cfs at Kansas City	(target flow plus 60,000 cfs)

7-04.18. **Coordination of System and Tributary Reservoir Flood Control Releases.** At Kansas City, the farthest downstream control point used for scheduling System releases, control of streamflow is also provided by tributary reservoirs located in the Kansas River basin. Flood control regulation criteria and techniques applicable to the Kansas River basin reservoir projects when this competition does not exist are described in the Kansas River Basin Master Manual and in the project manuals for individual Kansas River basin reservoirs. At times, however, competition will exist between the two reservoir systems for use of the available Missouri River channel capacity at Kansas City and downstream. When storage evacuation is required from the Kansas basin reservoirs, coordinated regulation of the two systems of reservoirs will proceed as described in the following paragraphs.

7-04.18.1. If the System water supply is such that a service level of 35,000 cfs or less is applicable, Kansas River basin reservoirs will have priority for the Missouri River channel capacity below Kansas City. Target flows on the Missouri River upstream from Kansas City will be reduced up to the minimum service level (if required) so that System releases do not contribute to forecasted Kansas City flows in excess of the current System service level flow value plus 66,000 cfs.

7-04.18.2. Releases from Kansas River basin reservoirs with accumulated flood control storage in Phase II or higher will have priority over System releases for the available channel capacity, irrespective of the current System service level. System releases will be scheduled as described in Paragraphs 7-04.16 or 7-04.17 after consideration is made of the effects of Phase II and Phase III releases from Kansas River basin reservoirs on Kansas City target flows.

7-04.18.3. If System storage evacuation requires a service level greater than the 35,000 cfs level, the System release requirements will have priority over releases from Kansas River basin reservoirs with accumulated flood control storage in the Phase I zone. Releases from the Phase I zone of Kansas basin reservoirs will be scheduled on the basis of System releases made in accordance with criteria given in Paragraphs 7-04.16 or 7-04.17.

7-04.18.4. During the period of flood storage evacuation from the Kansas River basin reservoirs, close coordination between the Corps' Kansas City District water control office and the RCC is required for the development of release schedules. This coordination consists of the following actions.

7-04.18.4.1. The Kansas City District Water Control Office will develop release schedules for their tributary reservoirs with storage levels in Phase II or higher and furnish the resultant forecasted flows of the Kansas River at Desoto, Kansas to the RCC in a timely fashion so that it can be integrated into the RCC's daily Missouri River streamflow forecast. Based on the above, the RCC will schedule releases from the System and furnish this schedule to the Kansas City District in the form of the RCC's Missouri River streamflow forecast. The Kansas City District will then take advantage of any remaining Missouri River channel capacity available at Kansas City and downstream Missouri River locations to schedule releases from reservoirs in the Phase I zone.

7-04.19. **Lower Missouri River Flood Flows.** Because the water travel time to Missouri River locations below Kansas City is over 6 days from Gavins Point Dam, the Kansas City flow target location is the most downstream location for which System releases will normally be scheduled based on a forecast. Experience has shown that predicted hydrologic conditions that could produce large rainfalls are only mildly accurate for periods 3 to 6 days in advance and are not accurate for periods more than 6 days in advance. If System release reductions will not result in missing flow targets and hydrologic forecasts indicate that System release reductions will result in flood damage reductions below Kansas City, a reduction in System releases will be scheduled. This should not be attempted if it will significantly impact System or tributary reservoir flood storage evacuation. Due to the long-range forecasts required and the current state-of-the-art forecasting technology, such System release reductions for this purpose will seldom be necessary except during severe, prolonged downstream flooding periods. Requests for coordinated flood storage evacuation from the System due to flooding on the Mississippi River have occurred in the past. This regulation has been requested even though there are no flood control targets below Kansas City or on the Mississippi River. These requests are rare and difficult to achieve because of the travel time involved. If System regulation changes can be accomplished without significant adverse affects, they should be attempted. There have been times when the RCC has also been requested to coordinate tributary reservoir releases from Corps' projects located in the Kansas City District to minimize flood crests on the Mississippi River. These actions have proven beneficial to preventing or reducing flood damages on the Mississippi River.

7-04.20. **Individual System Project Reservoir Regulation Techniques.** Volumes 2 through 7 of the Mainstem Reservoir Regulation Manual series present the details necessary for integrating regulation of the individual System reservoirs with System regulation described in this volume. Paragraph 1-02.1 in this manual presents an explanation of the Mainstem Reservoir Regulation Manual series. While regulation of many of the tributary reservoirs in the Missouri River basin is independent of System regulation, integrated regulation will, at times, be required. Paragraph 7-04.18 describes the coordination necessary in regulating Kansas River basin reservoirs. Individual System project manuals describe coordinated regulation with those tributary reservoirs that are most closely related with each individual System project, particularly those tributary reservoirs that have System replacement flood control storage, as described in Paragraph 7-04.4.1 of this manual.

7-04.20.1. During extreme floods approaching the magnitude of the greatest floods of historical record, it is quite probable that surcharge regulation will be required at one or more of the System projects. If such an event were to occur, System regulation would be conducted largely on a reservoir-by-reservoir basis and would be based on techniques described in the individual project manuals. System releases would be as defined by the Gavins Point procedures. In the event of a prolonged communications failure between the RCC and individual projects, System release rates would be scheduled according to the emergency procedures outlined in the individual System project manuals.

7-04.21. **Responsibility for Application of System Reservoir Regulation Techniques.** Due to the necessity for integrated regulation to secure the maximum degree of beneficial use from all System storage, the RCC will be responsible for, and will direct, the regulation of all the System reservoirs in accordance with the relationship between the RCC and District offices outlined in Chapter VIII of this manual. Such direction will normally be in the form of regulation orders to the System projects that specify releases to be maintained, the permissible fluctuations in this release rate, and the period through which the order will be applicable. The respective District offices provide personnel for operation and maintenance of the projects and are responsible for the physical manipulations necessary to carry out the directives.

7-04.22**. Responsibility for System Dam Safety and Emergency Regulation.** Although regulation procedures for the System and individual System reservoirs are normally developed in the RCC, it is the responsibility of the District to maintain adequate provisions for maintaining the integrity of the System dams at all times. The RCC will be informed, and a specific method of System or individual reservoir regulation may be recommended by the District, at any time it is believed that any part of a project's dam structure may be endangered by existing or anticipated conditions. In addition, the RCC will be advised when local flood conditions are such that improved conditions may result by specific methods of System reservoir regulation. The RCC will consider this information and field recommendations in conjunction with other known existing conditions in prior to issuing System project regulation instructions. If Corps staff believes that the integrity of a dam is endangered and communications with the RCC are not possible, the project office and/or the District office may modify instructions (regulation orders) to ensure the safety of the structure. When communication with the RCC is impossible and the projects are under emergency conditions, the District or project staff are entirely responsible for application of emergency regulation techniques. Paragraph 7-16 of this chapter contains a more detailed discussion regarding System emergency regulation procedures.

7-04.23. **Responsibility for Flood Control Reservoir Regulation Coordination in Missouri River Basin.** Normally, tributary reservoir regulation is a function of the Districts with pertinent reservoir regulation information furnished to the RCC. When tributary reservoir regulation affects Missouri River flood flows or navigation on the Missouri River, tributary reservoir regulation will, however, become a direct concern of the RCC. During such periods, the RCC will issue pertinent tributary reservoir regulating instructions so that flood damages may be held to a minimum through integrated regulation of all flood control reservoirs in the Missouri River basin. The appropriate District, with only nominal Division supervision, will direct tributary reservoir regulation during periods of tributary floods not extending to the Missouri River. The provisions of Paragraph 7-04.22 of this manual regarding safety of the project and conflicts between local and general flood protection will also apply to tributary reservoirs during periods when they are regulated as directed by the RCC. The Corps' Guidance Memorandum entitled, "Reservoir Control Center (RCC)", dated March 1972, serves as the document that details the role and responsibilities of the RCC in managing and regulating the System, including the coordination responsibilities for the regulation of tributary reservoirs during major flood control events.

7-04.24. **Reporting of System Flood Control Operations.** Status reports regarding System flood control operations are prepared by the RCC and provided to key Division and District offices on an immediate basis. The reports are normally distributed by email and/or posted to the internal Corps website. The Power Plant Control System (PPCS) allows RCC staff access to all System projects to obtain real-time System data such as instantaneous releases from each power unit, spillway releases, outlet tunnel flows, and reservoir elevations. This information is transmitted automatically to the RCC database on an hourly basis. Once these data are received in the RCC, reservoir storages and inflows are calculated. Even with all the project data available to the RCC, it is sometimes necessary and prudent for RCC staff to speak directly to the project staff to assess any potential problems with the project, its major features, or any matter that could affect future project release decisions. During severe flood periods, daily summaries of hydrologic conditions and reservoir regulation will be furnished to Office of the Chief of Engineers by the District Engineer. Various types of information relative to floods are required in the flood control operations status reports including reservoir name, reservoir elevation, forecasted maximum elevation and associated date, current and forecasted rates of inflow and outflow in cfs, percent of flood control storage used to date, and any other specific information pertinent to the flood situation. Coordination is required with the RCC prior to the Districts furnishing this information relating to the System to the Chief of Engineers.

7-04.25. **Monthly System and Tributary Reservoir Reports.** Each month, the RCC prepares a reservoir summary report, also referred to as an MRD 0168 Report, for each System project, indicating daily reservoir elevation, storage, inflow, release, and estimated evaporation. The appropriate District office prepares the same report for each of the Corps' tributary reservoirs and all USBR tributary reservoir projects having flood control as an authorized purpose. The

District reports are either provided to the RCC electronically or the data to create the report is available in the RCC database.

7-04.26. **Historical Examples of System Regulation During Major Floods.** Although Fort Peck was placed in operation in 1937, additional projects on the System were not operable prior to the 1950's and early 1960's. Limited System regulation was initiated in 1953, following the closure of the Fort Randall embankment in 1952 and Garrison in 1953. Gavins Point was closed in 1955, Oahe in 1958, and Big Bend in 1963. Although this completed the embankment closures on the System, regulation of the System was somewhat limited in the early years of regulation by project construction and the completion of real estate activities. In July 1966, installation of all of the present power units was completed, and the following summer the System reservoirs reached their base of the Annual Flood Control and Multiple Use Zones for the first time. Only since that time, have the individual System reservoirs, therefore, been regulated as a completely integrated System. Appendix A contains the historical examples of flood since the system was completed in 1967.

7-04.26.1. **System Storage Accumulation.** Initial fill of the System was accompanied during a period of below-normal runoff from the Missouri River drainage area above the System. Runoff was well below normal during each year of the 8-year period, extending from 1954 through 1961. The cumulative effect of these low-runoff years resulted in the second most severe drought period for the Missouri River basin since 1898. Runoff above the System averaged somewhat above normal from 1962 through the mid-1980's with well-above-normal amounts occurring in some years. The 6-year drought extending from 1987 through 1992, represented a particularly challenging System regulation period. The 1990's represent the highest runoff decade of the past century. As of the writing of this manual (March 2004), the System has been experiencing drought conditions since 2000. Plate VII-2 illustrates month-by-month accumulation of water in the System and its distribution in the individual System reservoirs. As shown on Plate VII-2, the Carryover Multiple Use Zone was first filled in 1967. Since 1967, the volume of water in System storage has generally remained within the Annual Flood Control and Multiple Use Zone that extends from 57.1 MAF to 68.7 MAF. The typical annual variation of the amount of water in System storage shown on Plate VII-2 reflects the normal accumulation of water-in-storage during the March through July flood season and normal evacuation of accumulated water to regain this space during the remainder of the year.

7-04.26.2. **System Regulation Effects on Streamflow.** The accumulation and evacuation of water in System storage has had a major effect on streamflow below the System. Plate VII-3 presents hydrographs of mean monthly flows at Yankton, South Dakota, which is immediately below Gavins Point Dam, since the System has been fully operational. The flows at Sioux City consist primarily of Gavins Point Dam releases. Unregulated flows are determined at various sites for the purpose of calculating flood damages prevented. Unregulated daily flows are determined by representing the regulated flows adjusted for upstream reservoir effects. The upstream reservoir effects include storage of runoff, evaporation from the reservoir surface, and precipitation directly on the reservoirs. The reservoir effects used in the development of unregulated flows include those from major tributary reservoirs and the System projects. The major portion of the reservoir effects results from regulation provided by the System. Unregulated flow development was on a mean daily basis, and only the mean monthly flows are shown on Plate VII-3.

7-04.26.3. The 1967, 1972, 1975, 1978, 1993, and 1997 hydrographs illustrate the effects of System regulation on substantial flood inflows. Plates VII-4 through VII-9 also illustrate characteristic patterns of releases from the System. Data to produce similar hydrographs that indicate System regulated versus unregulated flows are stored on the RCC database. The data are available for all years of regulation since 1950 and for other locations within and below the System. Complete write-ups for each year are on file as separate reports in the RCC.

7-04.27. **Regulation During Extreme Floods and During Emergencies.** The following paragraphs briefly describe the System flood control regulation procedures for extreme floods and during emergencies.

7-04.27.1. **System Regulation During Extreme Floods.** During extremely large floods that may use all of the flood control storage zone capacity provided in any of the individual System projects, regulation will primarily be based on conditions affecting that particular project rather than the System as a whole. Examples of regulation during this type of flood are, consequently, not included in this manual. Individual System project water control manuals address this subject with the Gavins Point manual providing the best example of System releases that could be expected to occur during such events. The effects from individual project regulation will be integrated into a System model to balance the effects throughout the System and afford greater flood control downstream than that provided by any one project. Paragraph 7-04.10.3 of this Master Manual describes the flood storage evacuation priority order for the System and individual projects. The System daily and long-range study simulation models discussed in Chapter VI include this evacuation priority as a normal regulation procedure. Further model refinement is provided by manually adjusting individual project and System releases to achieve the desired result.

7-04.28. **Emergency Procedures.** Regulation criteria in the event of a communications failure with the RCC are detailed in individual project manuals and their associated instructions to project personnel for such events. Examples of their application are contained in individual System project water control manuals.

7-04.29**. System Flood Control Storage Analysis.** This manual presents a new CWCP primarily making changes to the drought conservation measures used for System regulation. Normal and flood control System reservoir regulation procedures have not been changed, but they have been updated to reflect current conditions. The amount of System flood control storage space required has been analyzed in depth for the Master Manual Study. Results indicate that very little additional flood control benefit could be obtained from additional flood control storage space in the System. In general, much of the basin lies below the System. That fact has prevented, and will continue to prevent, the System from controlling all flooding along the Missouri River. Normally, enough vacant space exists in the System prior to the runoff season to control the significant floods that occur above the System, as demonstrated by the 200-percent-of-normal event that occurred in 1997. This storage normally provides the additional space needed to provide for an extensive reduction in System releases to control downstream flooding. The decade of the 1990's provided four of the top seven basin runoffs that occurred in the 106-year Missouri River basin historic runoff record (1898-2003). Regulation of these runoffs has refined the System flood control techniques described in this chapter and provided many examples of successful System flood control regulation. Study and refinement of System flood regulation techniques will continue along with research and development to improve the long-range forecasting of expected runoff in the Missouri River basin.

7-05. **Multipurpose Regulation Plans.** In the course of the planning, design, construction, and regulation of the System, many long-range regulation studies have been made to establish and demonstrate the capabilities of the System to meet the many project purposes and to establish criteria for planning, design and regulation purposes. Other shorter-term studies, on a continuing basis, lead to AOPs, 5-year projections, and many other special purpose plans. These studies provide a sufficient volume of predetermined vacant storage capacity at each of the System reservoirs at the beginning of the flood season; therefore, they recognize the flood control purpose. The daily routing model (DRM), which uses a daily time-step, serves as a useful tool in the examination of detailed flood control regulation criteria and the other project purposes.

7-05.1. **Long-Range Regulation Studies.** Long-range regulation studies of the System encompassing the hydrologic period from 1898 to the time of the study have been referred to previously in this manual, particularly in Chapter VI, Hydrologic Forecasts, Paragraph 6-04 Long-Range Forecasts, where some of the limitations of these studies were discussed. Major studies have been published and distributed to interested Corps offices, USBR, Western, and others. The RCC has a list of the major studies performed in the past and pertinent data as to the basic conditions assumed in their performance. Future studies by the RCC will be needed to evaluate proposed Adaptive Management actions and other regulation considerations as the System matures under this updated water control plan.

7-05.2. **Service to System Authorized Purposes.** The long-range regulation studies demonstrate the service (e.g., flows, reservoir levels, and power generation values) that the System is expected to provide for the basic purposes under various scenarios with differing levels of basin development and conditions of water supply. They also serve to examine variations in regulation criteria and in this manner keep criteria consistent with changing emphasis upon specific purposes through the years. The latest studies reflect current conditions (or near-term anticipated future conditions) and the service to purposes provided by the System under current criteria included in the Master Manual.

7-06. **Emergency Regulation Procedures (Standing Instructions to Dam Tender).** The Standing Instructions to the dam tender that would be used in the event that communication is lost with the RCC are contained in the individual System project water control manuals and are not repeated in this document. Those instructions are to be used only in the event of a significant communication failure over an extended period of time that results from a catastrophic event. The RCC uses real-time simulation modeling to effectively regulate the System and this cannot be replicated in the instructions to the dam tenders. These orders serve only as a temporary way of bridging the time period between not having orders and until RCC staff can run their models and issue new orders. The RCC normally schedules each of the System projects for more than one day into the future, many as long as the next week. It is unlikely, even in a significant communications failure, that the System projects would not have Power Production and Reservoir Regulation orders with which to regulate the project.

7-07. **Flood Control Purpose System Regulation.** The discussion of the planning and subsequent regulation for the flood control purpose of the System constitutes a major portion of this Master Manual. The planning of the sizing of the individual Mainstem project flood control zones is described above and in Appendix A. The reservoir regulation of the System for flood control is detailed in previous paragraphs. Storage of large runoffs in the System for multiple purpose use later by releasing during low-flow periods is consistent with the Congressionally authorized flood control purpose. Similarly, storage of water for the control of floods is also compatible, to a great extent, with multiple purpose regulation of the System. The flood control purpose of the System will be given the highest System priority during periods of significant runoff when loss of life and property could occur. Regulation efforts will be made to minimize these losses. The flood damage prevention provided by the System has been greater than originally envisioned because of the protection provided to the critical urban areas in the basin during the 1993 and 1997 flood events. Plate VI-2 identifies the flood damages prevented to date by the System. The $24.8 billion in accumulative damages prevented by the System exceeds the cost of building the entire System in today's dollars. Several specific years (1993, 1995, 1996, 1997, and 1999) have resulted in more than 60 percent of the total damages prevented, primarily due the protection of downstream urban areas located below the System. The unpredictability of these major flood events means that, to fulfill the flood control operational objective of the System, the Exclusive Flood Zone should be kept empty except during major flood events. This unpredictability also means that the System should normally be at the base of the Annual Flood Control and Multiple Use Zone (57.1 MAF) prior to the beginning of the flood season. The use of Plate VI-1 as a guide in determining the service level for evacuation of water captured in the Exclusive Flood Control and the Annual Flood Control and Multiple Use Zones and for normal and conservation regulation is discussed in Chapter VI and above. This plan was developed with the intent of fully meeting the Congressionally authorized flood control purpose.

7-07.1. **Flood Control Regulation Problems Associated with Stage–Discharge Variation and Channel Capacity Deterioration.** The following paragraphs discuss the problems associated with System regulation during flooding with regard to variation in the stage-discharge relationship on a seasonal basis and channel degradation.

7-07.1.1. **Seasonal Variations in the Stage-Discharge Relationships.** The Missouri River is an alluvial stream with a movable sand bed; consequently, marked variations in the relationship between stages and corresponding discharges occur. While some of these variations may be more or less permanent in nature due to changes in channel regimen, there is a seasonal shift in this relationship, particularly in the reach extending from Sioux City to Kansas City. Investigation indicates that this shift is related to water temperature and consequent bedform configuration. In essence, the typical seasonal shift results in higher stages during the mid-summer months than during the early spring and fall months for similar rates of flow. Stage variations of approximately one foot may occur as a result of these seasonal rating curve shifts. Gavins Point Dam releases are made to meet a downstream level of service (target flows) at Sioux City, Omaha, Nebraska City, and Kansas City. Evaluation of these service level requirements is based on the stage-discharge relationship at the above USGS gaging station locations. Accurate determination of flow based on observed stage at the gaging stations is difficult during the spring and fall water temperature shift period, requiring more frequent Missouri River discharge measurements and database corrections.

7-07.1.2. **River Channel Deterioration.** Evidence exists of a permanent shift in the stage-discharge relationship at numerous locations along the Missouri. This shift generally is in the direction of reduced channel capacity for higher flows and has been very significant at some locations. For example, below Fort Randall Dam and just upstream from the mouth of the Niobrara River, land areas adjacent to the river channel are now being inundated with flows less than 50,000 cfs. These same areas were dry with flows of over 150,000 cfs prior to the time that System reservoir regulation began. By the mid 1970's, the bankfull capacity was reduced to 60,000 cfs, and further reductions continued to 44,000 cfs in 1985 and 35,000 cfs in 1994. The high releases in 1997 resulted in an improvement in channel capacity when some deposits were scoured from the channel. Many similar instances could be cited, although generally not as extreme as the above example. The effects of these channel changes have been to reduce capacity and can be partly attributed to the control by the System of flood flows and their scouring effects. Some deterioration in channel capacity at some locations may have, however, resulted from bank stabilization measures that have been constructed for navigation or streambank erosion control purposes.

7-07.1.2.1. Conversely, in some Missouri River reaches, evidence exists of significant degradation, or lowering, of the Missouri River channel. As expected, degradation has occurred downstream of the System powerplants. In these cases, degradation has been considered beneficial, as increased power heads result that allow a greater amount of power production. On the Missouri River below the System, particularly in the Missouri River reach from Gavins Point Dam to Omaha, river stages have decreased markedly since System regulation first began in 1954. This degradation has had adverse effects on; recreation facilities, water intakes, well fields, navigation docks, tributary channel stability, and wetland habitat. The degradation has had a positive effect on flood control, as channel capacity has improved and areas that were once subject to flooding are now high and dry during significant release increases. For example, the flood control situation has been significantly improved for moderate floods in both the Dakota Dunes area near Sioux City and the Kansas City urban area because of additional channel degradation during the 1990's.

7-07.1.3. **Flood Control Regulation Problems Associated with Interior Drainage and Groundwater.** Also of concern is the effect of higher System releases during prolonged flood evacuation periods on interior drainage and groundwater tables in the reach of the Missouri River below the System. Higher Missouri River levels below the System make the draining of runoff that falls on cropland difficult, if not impossible, especially because the levee system constructed generally depends on draining into the Missouri River. Higher Missouri River levels also result in higher groundwater levels that make planting and harvesting crops difficult or impossible for farmland located just adjacent to the Missouri River. This is especially true in the aggradation reach just below the confluence of the Platte River with the Missouri River in Nebraska. Consideration is given to the effects of interior drainage and high groundwater levels in any prolonged flood control System regulation event.

7-07.1.3.1. Development of flood damageable property in flood-prone areas has been general and extensive throughout the entire reach of the Missouri River, especially in the areas downstream of the System projects. When higher-than-normal releases are required from System projects, flooding of floodplain lands and developments can, and should be, expected. The capture and metering of flood flows during the remainder of the year can also result in higher releases during late summer and fall. This period is normally not a high-runoff period, but, for those low-lying areas immediately adjacent to the Missouri River, poor drainage conditions are a continual concern.

7-07.2. **Other Flood Control Regulation Challenges.** The regulation of the System during years when the annual runoff is approximately equal to or greater than 30 MAF has occurred many times since the System became operational in 1967. The most significant flood runoff years are 1975, 1978, 1984, 1986, 1993, 1995, 1996, 1997 and 1999, all of which are documented in detail in the flood history of Appendix A. The 1975, 1978, and 1997 years stand apart from the others in the severity of the events. Most of the concerns arose from high pool elevations and passing the large volumes of water through the existing outlet works and into limited downstream channels to evacuate flood storage. The following should be recognized in a typical flood control situation.

7-07.2.1. System releases will be reduced to a minimum level to protect and minimize the loss of life and property downstream in all river reaches during significant flood events. The releases are never reduced to zero, because this would have significant negative impacts for just a small improvement in downstream flood control. Over-reaction in the form of reducing releases to extremely low levels early in the runoff season may result in significantly less capability to control flooding, should a significant flood event or a succession of lesser flood events occur later. The System has a finite amount of storage available for flood control, and it should be used judiciously.

7-07.2.2. All reasonable attempts will be made to evacuate all of the water that is captured or retained in the System above the base of the Annual Flood Control and Multiple Use Zone prior to the following March 1. Most of this volume will be evacuated by December 1, prior to the onset of winter release restrictions due to expected limited winter releases because of river icing.

7-07.2.3. The System does not guarantee a flood-free zone in the Missouri River reaches between the System reservoirs and below the System. Downstream flooding will occur even if releases are reduced to minimums from the System dams because enough uncontrolled area exists downstream from several of the dams to cause major flooding if significant rainfall occurs. The potential extent and amount of damage caused by this runoff varies. Lack of floodplain zoning to discourage development in flood-prone areas will result in higher flood damage in the future even with the flood protection provided by the System.

7-07.2.4. If a flood occurs below the System, the damages are likely to be greater than if the same volume of flood occurs in reaches within the System because the major urban centers that exist below the System have a greater potential for very high flood damages. Two Missouri River reaches within the System below Garrison and Oahe, also have large cities on the floodplain, and the potential flood damage in these reaches is also very significant.

7-07.2.5. During past major flood events, a concern has developed that the upper three System reservoirs rise too high into their Annual Flood Control and Multiple Use and Exclusive Flood Control Zones. In 1975, a large rainfall event occurred in eastern Montana, and Fort Peck reached a maximum elevation that was 1.6 feet above its maximum operating level, or 1.6 feet into the surcharge zone provided for the control of extraordinary floods. Only Federal lands acquired for project purposes were inundated. Also in 1975, Garrison's maximum level reached elevation 1854.8 feet msl, or 0.8 foot into the surcharge zone but below the 1855-foot msl guide taking line for land acquisition. The majority of the concerns relating to high reservoir levels were received from the headwaters' area of the Garrison project. Lands affected were Federally-purchased lands affected by the backwater effects of both high reservoir levels and large inflow rates. These were lands leased to private individuals, subject to flooding if required for project regulation. Concerns were also voiced over flooding on the Missouri River near the mouth of the Yellowstone River, upstream of the taking line; however, this land was flooded by high river flows, rather than by Lake Sakakawea. During the large plains and mountain snowmelt flood of 1997, Garrison again exceeded the maximum normal operating level following a large, local rainfall event after it had successfully captured snowmelt runoff. Oahe has been in its Exclusive Flood Control Zone several times during the 1990's, prompting concerns about high, prolonged reservoir levels at this System project. The RCC recognizes that encroachment has occurred into the surcharge zone of some System projects. This, however, has not reduced the effectiveness of these projects to control flood inflows. All studies to date have indicated that there is no long-term problem associated with having the large System projects in their Exclusive Flood Control Zones. This zone is designed to store water during major flood events and the maximum project benefits cannot be obtained unless this zone is used, when appropriate. Releases from System projects with water in their Exclusive Flood Control Zones should be increased to the maximum practical in order to use downstream channel capacity so that the Exclusive Flood Control and the Surcharge Zones are vacated as soon as possible to allow storage space for subsequent runoff, should it occur.

7-07.2.6. A question has arisen in recent years whether or not project releases should be increased to higher levels earlier in the season to lower maximum release rates and reservoir levels. This is a common practice for snowmelt-type flood events; however, this approach does not apply to rainfall events that cannot be predicted. With snowmelt events, the actual conditions during the melt heavily influence the amount of runoff volume produced. Unfortunately, the temperatures and associated rainfall during snowmelt, the most significant variables, cannot be reliably predicted. This results in a wide range of potential runoff volume for the same amount of accumulated snow. Releasing at higher-than-normal rates early in the season that cannot be supported by runoff forecasting techniques is inconsistent with all System purposes other than flood control. All of the other authorized purposes depend upon the accumulation of water in the System rather than the availability of vacant storage space. Unnecessary drawdown of water in the System would not achieve the regulation objective of optimizing service to all authorized purposes.

7-07.2.7. Bank erosion along the unstabilized portion of the Missouri River channel has been an ongoing concern. Data available to the Corps indicate that average erosion rates through the unprotected areas since full System regulation began in 1967 are less than during pre-project conditions, although this improvement is small in some Missouri River reaches.

7-07.3. **Missouri River Open-Water Channel Capacities.** A brief summary of present open-water channel capacities for specific Missouri River reaches is given below. Discussion of ice-affected channel capacities is presented in 7.04-9.

7-07.3.1. **Fort Peck Dam to the Mouth of the Yellowstone River.** Damages in this reach begin with open-water flows of 30,000 cfs; however, with flows ranging from 50,000 cfs in the upper portion to 70,000 cfs in the lower portion of the reach, damages are relatively minor and limited mainly to pasture and other unimproved lands.

7-07.3.2. **Garrison Dam to Lake Oahe.** The main damage center in this reach is Bismarck. If Bismarck stages are not allowed to rise significantly above 13 feet, few flood damages are observed. Flood stage at the Bismarck gage is 16 feet. At the time Garrison Dam was constructed, this represented an open-water channel capacity of about 90,000 cfs; however, in 1975, after 20 years of reservoir regulation, the channel had deteriorated to the extent that open-water flows of about 50,000 cfs resulted in a stage of 13 feet. This is due in part to the Oahe delta affect just downstream of Bismarck. A substantial amount of floodplain development has occurred at low levels in the Bismarck/Mandan vicinity.

7-07.3.3. **Big Bend Dam to Lake Francis Case.** During the 1991 fall drawdown of Fort Randall, it was observed that the White River delta, which extends across Lake Francis Case, was having a damming effect that created different lake elevations upstream and downstream of the delta. In recent times, the upper reservoir elevation has been as much as 6 feet higher than that for the reservoir downstream from the delta. The Corps has published a revised elevation capacity table for Lake Francis Case reflecting the effect of this sedimentation near elevation 1347 feet msl and below.

7-07.3.4. **Fort Randall Dam to Lewis and Clark Lake.** Since System regulation began, a delta has formed at the mouth of the Niobrara River, a stream that enters the Missouri River just upstream from Lewis and Clark Lake. Prior to System regulation, large flood flows periodically removed the delta material; however, these large floods are now eliminated by upstream System control. While this reach of the Missouri River was capable of passing flows in excess of 150,000 cfs prior to construction of the System projects, Fort Randall Dam open-water releases of 40,000 to 50,000 cfs now result in flood problems to adjacent property owners.

7-07.3.5. **Gavins Point Dam to Sioux City.** Prior to construction of the System, the open-water channel capacity through this reach of the Missouri River was well in excess of 100,000 cfs. There is evidence of channel deterioration due largely to encroachment in backwater areas and along old river meander chutes; however, this is partially offset by channel degradation. In 1997, sustained flows of 70,000 cfs in this reach caused some damage. The open-water channel capacity has increased in this reach to nearly 100,000 cfs since 1995 by the additional degradation of approximately 3 feet.

7-07.3.6. **Sioux City to Omaha.** Open-water channel capacity in this reach prior to construction of the System was in excess of 100,000 cfs. During recent years, there has been considerable encroachment on the channel area. Fixed boat docks have been constructed in numerous locations through this reach, and low areas are now being farmed. Much of this development is on or adjacent to river stabilization structures and takes advantage of sediment deposition encouraged by this stabilization. Adversely affecting the channel and floodplain developmental encroachment is the channel degradation in this reach. Degradation, while increasing the channel flood capacity, has adversely impacted marinas, water intakes, and tributary channel stability.

7-07.3.7. **Omaha to St. Joseph.** Deterioration of the channel capacity has occurred through this reach. Recent experience indicates that mid-summer flows exceeding 90,000 cfs will result in river levels above flood stage at Nebraska City and Rulo, Nebraska and St. Joseph, Missouri. Damage due to high groundwater and interior drainage behind levees in cultivated fields begins at stages two or more feet below flood stage.

7-07.3.8. **St. Joseph to the Mouth of Missouri River Near St. Louis.** Open-water flows of about 150,000 cfs will cause only relatively minor agricultural damages in this reach; however, the established flood stage at Waverly, Missouri, has been exceeded when flows were greater than 115,000 cfs during recent years.

7-08. **Recreation Purpose System Regulation.**   Historic System regulation to serve the recreation purpose is detailed in Appendix B of this Master Manual. Numerous adjustments of both a temporary and a relatively permanent nature have been made to the regulation of individual System projects to enhance recreational activities. For example, a limitation is placed on power peaking during particular periods in order that downstream boating or fishing tournaments may be facilitated. Recreational use of the System has increased through the years, with the visitor-hour attendance approaching or slightly exceeding 60 million visitor hours during the past seven years.

7-08.1. Reservoir levels in the upper three, larger System reservoirs during drought were a main focus of the Master Manual Study that was the basis for the selection of the CWCP presented in this document. Application of the specific technical criteria for the CWCP discussed previously in this chapter would improve benefits provided to lake recreation as compared to the former water control plan.

7-08.2. The three smaller System projects are not affected to any significant degree by extended drought because their levels are basically unaffected by changes in the annual water supply and total System storage. Only if a drought were more severe than that experienced in the 1930's, would the elevation in Lake Francis Case be reduced to levels lower than the normal annual cycle.

7-09. **Water Quality Purpose System Regulation.** Historic System regulation to serve the water quality purpose is detailed in Appendix C of this Master Manual. Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health, plant and animal life, and the various uses of water by man (irrigation, domestic, and industrial uses); temperatures, which affect fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor, and floating materials, which affect the water's potability and the aesthetic quality of the environment. The level of dissolved solids concentrations has been a concern historically. Biologic quality and dissolved-oxygen quality have not been considered problems within the basin until recent years. As a result, there has not been a long-term watershed approach in obtaining area-wide data, but it is known that problems exist below several of the major cities and below industrialized areas on some of the smaller tributary streams. High ambient air temperatures, solar radiation, water depth, and thermal discharges from point sources can also affect thermal water quality conditions. Low releases could impact the operation of downstream powerplants.

7-09.1. **System Downstream Release Requirements for Water Quality.** Generally, System project release levels necessary to meet the downstream water supply purposes exceed the minimum release levels necessary to meet minimum downstream water quality requirements. Tentative flow requirements for satisfactory water quality were first established by the U.S. Public Health Service and presented in the 1951 Missouri Basin Inter-Agency Committee Report on Adequacy of Flows in the Missouri River. These requirements were used in System regulation until revisions were made in 1969 by the Federal Water Pollution Control Administration. The Missouri River minimum daily flow requirements for water quality that are given in Table VII-9 were initially established by the Federal Water Pollution Control Administration in 1969. They were reaffirmed by the Environmental Protection Agency in 1974 after consideration of (1) the current status of PL 92-500 programs for managing both point and non-point waste sources discharging into the river, and (2) the satisfactory adherence to the dissolved-oxygen concentration of 5.0 parts per million (ppm). The minimum daily flow requirements listed in Table VII-9 will be used for System regulation purposes. The intent of this CWCP is to fully meet applicable water quality requirements and to continue to monitor the reservoirs and releases from the System to assure that this occurs.

Table VII-9
Minimum Daily Flow Requirements Below the System
for Adequate Dissolved Oxygen
(cfs)

Urban Area	December January February	March April	May	June July August September	October November
Sioux City	1,800	1,350	1,800	3,000	1,350
Omaha	4,500	3,375	4,500	7,500	3,375
Kansas City	5,400	4,050	5,400	9,000	4,050

7-09.2. **Other Water Quality Considerations.** The System and its regulation have significantly improved water quality in the river reaches between the reservoirs and downstream of the System, compared to the water quality in the Missouri River before the System was constructed. Downstream flow support from the System for the authorized purposes other than water quality more than meets the minimum flow requirements for Missouri River water quality. Water quality, therefore, has more than enough flow during all periods of the year in all of the Missouri River reaches with the CWCP. Water quality in the System reservoirs has been deteriorating for some time, essentially since the reservoirs were first filled. The dissolved-oxygen levels in the lower levels of the System reservoirs do not provide water quality conditions conducive to support some types of fish. The number of algae blooms has increased during the life of the System. Water quality has deteriorated in some arms of the large reservoirs for short periods so that the water in these locations is not potable, but these situations have been rare. In general, the water quality in the System reservoirs is considered good and is expected to remain so. Low flows in the reaches downstream from Garrison and Gavins Point Dams directly affect the ability of thermal powerplants in these two reaches to meet National Pollutant Discharge Elimination System (NPDES) permit standards for discharging cooling water back into the Missouri River. Low reservoir levels and river stages may increase the sediment content in water supplies.

7-10. **Fish and Wildlife Purpose System Regulation.** Historic System regulation to serve the fish and wildlife purpose is detailed in Appendix D of this Master Manual. Declining water levels of the reservoirs are a concern to many project users interested in the reservoir fishery; however, some fluctuation in the reservoir levels is unavoidable if the reservoirs are to serve all of the authorized purposes. Regulation to benefit reservoir fisheries is also discussed in Appendix I.   A continuing objective in the regulation of the System is to minimize the departures in reservoir levels from normal, full multipurpose levels to the maximum practical extent consistent with regulation for other authorized project purposes. The partial elimination of the annual drawdown of Lake Francis Case, which was previously discussed, is a good example of limiting reservoir level fluctuations while continuing to meet authorized purposes.

7-10.1. The maintenance of relatively uniform release rates during certain times of the year is also an environmental objective to benefit certain riverine species during their spawning period. Minimum releases are also required from some of the projects for downstream fisheries. System regulation has reduced high flows and supplementing low flows that still naturally occur on the Missouri River, which allows requests by State game and fish agencies to be met. Relatively constant releases, however, are not desirable for all fish species.   Some fluctuations in release rates continue to be unavoidable if all of the authorized System project purposes are to be served. Additionally, access to the river may be more difficult at times, fishing success may be affected, the sediment load in the river may be increased, and use of fixed boat docks may be inconvenienced. To the extent practical, considering release requirements for other authorized purposes, release fluctuations are being minimized.

7-10.2. **Minimum System Releases for Fish and Wildlife.** Establishment of minimum releases and steady-to-rising pools during the spring months have been recognized since the 1950's as beneficial for successful fish spawning and hatching. An ad-hoc committee of the American Fisheries Society first made recommendations to the former Missouri River Division Reservoir Control Center in 1972 regarding regulation activities beneficial for the fishery. This committee was replaced with the MRNRC, which was established in 1987 to provide the Corps with a coordinated recommendation for fishery enhancement. The MRNRC is comprised of representatives from fish and game agencies from the seven states bordering the Missouri River.

7-10.2.1. **Fort Peck Minimum Release.** Minimum hourly releases, particularly during fish spawning, have been requested from Fort Peck, Garrison and Fort Randall Dams for many years. These requests are implemented if other project purposes are not affected. A year-round instantaneous minimum release of 3,000 cfs was established at Fort Peck in 1992 for the trout fishery located in the dredge cuts immediately below Fort Peck Dam. This minimum was raised to 4,000 cfs in 1995 and has been in place since, except in the spring of 1997 when releases were lowered to 3,000 cfs as part of a System flood control operation to reduce inflows to a rapidly rising Lake Sakakawea.

7-10.2.2. **Garrison Minimum Release.** Garrison Dam minimum releases are established by standing orders that call for a minimum generation over a specified number of hours depending on a range of daily average project releases. In most years, the minimum hourly generation resulting from release patterns for least terns and piping plovers is higher than the minimum specified in the standing orders. The minimum daily average Garrison Dam release is 9,000 cfs to avoid excessively low stages at downstream water intakes.

7-10.2.3. **Oahe Minimum Release.** A 3,000 cfs minimum Oahe Dam release during daylight hours is normally established in early April to enhance downstream fishing and boating use during the recreation season.

7-10.2.4. **Fort Randall Minimum Release.** Minimum releases from Fort Randall Dam are imposed for fish spawning below the project in years when daily average releases are sufficiently high. The most recent MRNRC recommendation is a minimum of 9,000 cfs from April through June.

7-10.2.5. **Gavins Point Minimum Release.** The minimums under the CWCP for other purposes exceed current fishery minimum requirements.

7-10.3. **Modified System Regulation for Threatened and Endangered Species.** Releases from all projects except Oahe and Big Bend have been modified to accommodate endangered interior least tern and threatened piping plover nesting since 1986. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Fort Peck and Garrison peaking is limited to 4 of 5 units for no more than 6 hours each day. Fort Randall peaking is limited to 7 of 8 units for no more than 6 hours per day. Deviations from this CWCP to address ESA requirements will normally be provided in the AOP.

7-10.3.1. **Gavins Point Cycling.** During the early years of System regulation for endangered species, a technique of increasing project releases every third day by 8,000 to 10,000 cfs was used to encourage terns and plovers to build their nests on higher habitat so that these nests would not be inundated later when increases were required to meet the regulation objectives of the System. This pattern of increasing releases every third day was referred to as “cycling.” Cycling has not been used in recent years because of the potential harm to native fish and the risk of stranding chicks. Every third day “cycling” of Gavins Point Dam releases during release reductions for downstream flood control has continued to be used to keep birds nesting at sufficiently high elevations to maintain room for release increases when downstream flooding has subsided. The variation in releases is normally limited to 8,000 cfs to minimize adverse affects on downstream river users and fish.

7-10.3.2. **Gavins Point Steady Release.** Another technique, called “steady release,” is to increase the Gavins Point Dam release by early to mid-May when the terns and plovers begin to initiate nesting activities to the amount expected to be needed in August when downstream tributary flows are typically lower. This uses an additional amount of water stored in the System but usually preserves the ability to support downstream flow objectives and meet endangered species objectives as well. This type of release from Gavins Point Dam has been successfully used many times since system regulation for threatened and endangered species nesting began.

7-10.3.3. **Gavins Point Flow-to-Target Release.** Prior to the System regulating for endangered species, a "flow-to-target" approach was taken where releases from the System were increased as needed to provide downstream flow support. While this approach preserved the most habitat during the initial nesting phase, it normally resulted in the inundation of nests as downstream tributary flows fell off and Gavins Point Dam releases were increased to meet downstream target flows.

7-10.3.4. **Gavins Point Steady Release – Flow to Target.** During the 2003 nesting season, a new procedure, called "steady release – flow to target" was used to set the Gavins Point Dam release. This procedure combined features of the original "flow-to-target" method with the "steady release" plan. It called for an initial steady release high enough to inundate low-lying habitat that would likely be subject to inundation later in the season. As downstream tributary flows declined through the summer, releases could be increased as needed, within the limits of the Incidental Take Statement provided by the Service in its Supplemental BiOp prepared for the 2003 AOP, to meet downstream flow support for navigation and other authorized purposes.

7-11. **Water Supply and Irrigation Purpose System Regulation.** Historic System regulation to serve the water supply and irrigation purpose as well as intake locations are detailed in Appendix E of this Master Manual. Tribal intakes are presented as well in Appendix E. Numerous water intakes are located along the Missouri River, both within and below the System. These intakes are primarily for the purposes of municipal water supplies, nuclear and thermal powerplant cooling, and irrigation supplies withdrawn directly from the Missouri River. Historically, water access problems have been associated with several of these intakes; however, the problems have been primarily a matter of sandbars or sediment deposition at the intake restricting access to the river rather than insufficient water supply. Other water supply problems can occur during the winter months due to ice jamming on the river. Floating or frazil ice can also block the water intake facilities directly, which can reduce flow to unacceptable rates.

7-11.1. **System Water Supply Considerations.** The minimum daily flow requirements established for water supply are designed to prevent operational problems at municipal and thermal powerplant intakes at numerous locations along the Missouri River below the System. The lower Missouri River is significant with regard to water supply because 94 percent of the population served and 75 percent of the thermal power generating capacity using the Missouri River for once-through cooling are located below the System. Problems that have been experienced within the System are related primarily to intake elevations or river access rather than inadequate water supply. Evaluations are continuing by appropriate State agencies in coordination with water plant operators to determine the minimum stage and flow requirements at each intake location for satisfactory hydraulic operation. During any non-navigation time period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the Systems dams, to the extent reasonably possible. The minimum required summer release below minimum service rates to fully meet the water supply and water quality needs has not been established because this release has not been tested. In 2003, a 21,000 cfs release for only a few days resulted in downstream water supply problems. It is not known if these facilities could be modified to function at lower levels. An 18,000 cfs flow target was modeled during the development of this CWCP as a potential minimum water supply flow target rate in the summer months, which may result in some adverse impacts to power generation to comply with the water quality requirements for temperature. Lower flow targets of 9,000 cfs are included in the non-summer, open-water-season months, and these releases may not be adequate to meet water supply needs below the System on the Missouri River without modifications to some intakes, particularly those in the degradation reaches at Sioux City and Kansas City.

7-11.2. **Water Supply.** The growth in the use of the Missouri River for water supply as an authorized purpose has, like recreation, exceeded all original expectations. The RCC recognizes the importance to regulate the System in a manner to provide sufficient streamflow in intervening reaches between the System reservoirs and in the lower Missouri River reach from Gavins Point Dam to the mouth near St. Louis, Missouri, to sustain public water supplies of the numerous communities along the banks of the Missouri River. More than 1,600 intakes and intake facilities have been identified on the reservoirs and in the river reaches (Table E-1). Of these, 302 intakes and intake facilities are identified for American Indian Tribes. Appendix E and Section 2-10 discuss water supply intakes using the Missouri River. These intakes are primarily for municipal, industrial, and individual water supplies; fossil and nuclear-fueled powerplant cooling; and irrigation withdrawals directly from the Missouri River. In recent years, problems have been associated with several of these intakes; however, the problems have been a matter of intake access to the water rather than insufficient water to supply or meet requirements. The lower river reach is very reliant on the river for water supply because 94 percent of the population served, as shown in Table E-1, is located downstream of the System. In addition, 75 percent of the generation by thermal powerplants using the Missouri River, as shown in Table E-2, is located below the System. The following paragraphs discuss water supply for the reaches between the System projects and below the System. The purpose of this plan is to fully meet these water supply requirements to the extent reasonably possible. The Corps will continue to obtain the necessary data and make adjustments to the System to assure that this occurs; however, the intake access associated with obtaining Missouri River water is the responsibility of the entity choosing to use this source of water for its supply. Intake access problems are the responsibility of the intake owner, and the Corps will not guarantee access only that the supply of water in the Missouri River is adequate to meet this project purpose.

7-11.3. **Minimum System Release Requirements for Water Supply and Irrigation – Open-Water Season.**

7-11.3.1. **Fort Peck.** Historic regulating experience indicates that a minimum daily average release of 3,000 cfs from Fort Peck Dam is satisfactory for municipal water supply. During the spring and fall, instantaneous releases of no less than 4,000 cfs are normally scheduled for a downstream fishery. The irrigation demands below Fort Peck Dam during the irrigation season currently call for a flow of 6,000 cfs as a minimum; however, the formation of sandbars has at times restricted flows to some intakes in this reach. The Fort Peck Dam minimum release rate is, therefore, greater than the minimum water supply release requirement for this reach.

7-11.3.2. **Garrison.** At Garrison Dam, a minimum average daily release of at least 9,000 cfs during both the open-water and ice-cover seasons is desirable to provide sufficient river depths for satisfactory operation of municipal, irrigation, and powerplant water intakes in North Dakota. In this reach of the river, fluctuations in release levels at times require the resetting of irrigation pumping facilities to achieve access to available water or to prevent inundation of pumps.

7-11.3.3. **Oahe and Big Bend.** No restriction on minimum releases from Oahe and Big Bend is necessary for adequate service to water intakes because the headwaters of downstream reservoirs may extend to near the upstream dam sites. Minimum flows from Oahe of at least 3,000 cfs are normally made during the daylight hours during the recreation season.

7-11.3.4. **Fort Randall.** Mean daily releases of 1,000 cfs are considered to be adequate to meet all of the water supply requirements below Fort Randall Dam except for the city of Pickstown, South Dakota. This city has, in the past, needed a minimum of 12,000 cfs for 12 hours every third day to fill its water supply storage tanks. The city has recently connected to a rural water supply system that should eliminate this requirement in the future.

7-11.3.5. **Below Gavins Point.** When the water-in-storage in the System is at normal or higher levels, releases for the navigation and power production purposes and to evacuate flood control storage during the navigation season and winter period will normally be at levels that are deemed to be sufficient for the downstream water supply needs. During extended droughts, Gavins Point Dam releases are reduced. During any non-navigation time period, releases will be made to ensure adequate flows to serve water supply in the river reaches downstream of the System and between the Systems dams, to the extent reasonably possible. Some intakes require more than 9,000 cfs (minimum release required in the early 1990's) during the open-water season for effective operation. These intakes should be modified as soon as possible to ensure that they can remain operational as the Corps continues to pursue lowering the Gavins Point Dam release in the non-navigation months during drought periods to this rate. A winter Gavins Point Dam minimum release rate of 12,000 cfs has been established as the guide in meeting downstream water supply requirements during this period. Intakes typically have higher requirements during the winter period because of the effects of river ice in reducing the capacity of their intakes. If Gavins Point Dam release rates are reduced below 12,000 cfs for water conservation, continued surveillance of these intakes will be required, and, if appropriate, additional releases may be required to assure adequate water levels for uninterrupted intake operation. During the critical and more difficult winter period, release rates may be adjusted according to river icing conditions to assure that the water supply service is provided downstream. During drought years when System storage is low enough to reduce or eliminate the navigation season, a Gavins Point Dam release of 18,000 cfs has been established as meeting the summer water supply requirement. Intake owners should modify their intakes as soon as possible if a summer Gavins Point Dam release rate of 18,000 cfs will not be adequate to meet their needs.

7-11.4. **Irrigation Purpose System Regulation.** Federally-developed irrigation projects served directly from the System were envisioned and the pumping plants to support these irrigation projects from Garrison and Oahe were constructed. The Federal irrigation projects have not been constructed. The Oahe Diversion project was deauthorized, and the Garrison Diversion project has been significantly scaled back. No acres are currently irrigated with the Garrison Diversion project. Current plans for water resource development in the Missouri River basin do not include significant Federal irrigation development from the System. Releases from the reservoirs are used by numerous private irrigators and by Federally-financed projects. Private irrigation directly from the reservoirs is also continuing to develop. While the minimum releases established for water quality or for satisfactory operation of Missouri River water supply intakes are usually ample to meet the needs of irrigators, low reservoir levels and low river stages, with their associated exposure of sandbars and drying up of secondary channels, make access to the available supply difficult or inconvenient to obtain. Instances of such occurrences are discussed in the individual System project water control manuals. The System will continue to regulate for this Congressionally authorized project purpose and adjust releases to meet needs. As previously discussed, access is the major problem for all types of intakes along the Missouri River and on the System reservoirs. Generally speaking, access to Missouri River water for irrigation is the responsibility of the entity owning the intake.

7-12. **Hydropower Purpose System Regulation.** Historic System regulation to serve the hydropower purpose is detailed in Appendix F of this Master Manual. Since completion of the power installations at the System projects, most System project releases have been made through the respective powerplants. When release requirements were exceptionally high due to flood control storage evacuation, spillway releases were necessary at Gavins Point Dam. Some spills have also been required at Fort Peck, Garrison and Fort Randall Dams for this purpose; however, in most years releases from all projects are made through the powerplants at all times. The six System dams support 36 hydropower units with a combined plant capacity of 2,436 megawatts (MW) of potential power generation. These units provide an average of 10 million MWh of energy per year, which is marketed by Western. Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System; however, adjustments are made, when possible, to provide maximum power production during the summer and winter when demand and value of this authorized purpose is highest. Hydropower is the only Congressionally authorized purpose of the System that actually returns money to the Federal Treasury.

7-12.1. Realization of the maximum power potential provided by the water passing through the dams of the System requires that hydropower operations be carefully integrated into regulation of the overall System. This requires consideration of many factors, including generating capacity at each plant, marketability and current market price of generated power, necessary peaking capability, anticipated long-range storage balance requirements, regional power emergencies, and others. Regulation of the System projects is scheduled to develop the maximum power benefits to the extent reasonably possible.

7-12.2. **Hydropower Modifications for Transmission Loading Relief.** Pursuant to the Federal Energy Regulatory Commission’s open access transmission law, Western was requested to reduce generation on the System hydropower system during the spring and summer of 1997 to preserve transmission capability. This “transmission loading relief” (TLR) is accomplished on a very short notice at any time of the day and is performed by reducing the load at one or more System hydropower plants for an unforeseen duration, although usually for just a few hours. TLR was normally accomplished at Oahe in 1997 but also occurred at Fort Randall and Garrison. The relief involved shedding anywhere from a few MW to a few hundred MW with an accompanying reduction in System project release. Corps project personnel were then pressed into service to initiate supplemental releases through outlet works other than the powerplants to compensate for the reduced powerplant releases. During 1997, the volume of runoff was twice that in a normal year, and even a few hours of reduced releases could have become critical. Evacuation of the record runoff in 1997 caused releases to exceed powerplant capacity at all projects except Big Bend. TLR has been frequently provided by the System powerplants, particularly Oahe, since 1997. Lower runoff associated with the current drought has resulted in reduced generation since the record high set in 1997, and TLR requirements have eased due to lighter loading of the generating units. When high runoff years return, TLR is expected to be a consideration in regulation of the System.

7-12.3. **Hydropower Considerations – Annual Fort Randall Drawdown.** A disparity exists between summer power generation, when releases from four of the six System projects are relatively high to provide Missouri River downstream flow support, and winter generation, when System releases to the lower river must be restricted due to the limited ice-covered channel capacity. The effect of this disparity may be eased by another aspect of System regulation, the draft and refill of a portion of the Fort Randall Carryover Multiple Use Zone storage space. During this regulation, Oahe and Big Bend releases are reduced several weeks before the end of the navigation season. This leaves the water in Fort Randall as the primary source for downstream release requirements for the remainder of the fall season, a process that results in evacuation of a portion of its Carryover Multiple Use Zone storage space. This vacated storage space is then refilled with Oahe and Big Bend releases following the navigation season through the winter period. Whereas, the volume of winter releases from Oahe and Big Bend, in the absence of this recapture, would be about equal to those from Fort Randall, the refill of the evacuated Fort Randall space allows winter releases from these upstream projects to substantially exceed those from Fort Randall Dam.

7-12.3.1. During the period of initial fill and the regulation of the System in years prior to 1971, as much as 2 MAF of storage below the base of the Annual Flood Control Multiple Use Zone was drawn out of Fort Randall. The recapture of the evacuated storage space allowed Oahe and Big Bend releases to exceed Fort Randall releases by an average of 8,000 cfs for the winter. This regulation resulted in substantially more winter energy generation, exceeding 300,000 MWhs, when Oahe was at its normal level. Offsetting this gain in System generation, the generating capability at Fort Randall Dam was reduced by 60 to 70 MW in early December because of the lower reservoir level; however, this negatively impacted other System authorized purposes. A lowered Lake Francis Case has an adverse effect on recreation in and around the reservoir area while the exposed reservoir floor becomes undesirable in an esthetic sense. Mud flats in the reservoir headwaters spawned blowing dust storms near Chamberlain, and boat ramps were out of the water. The effects of this drawdown on the surrounding environment became an increasing concern, particularly when this drawdown proceeded below elevation 1340 feet msl. Studies conducted in 1971 and 1972 resulted in a compromise being accepted that limited the drawdown of Fort Randall to elevation 1337.5 feet msl in most years. The drawdown to this level was also delayed as late as possible in the year so that any negative impacts were felt for the shortest possible period of time. This drawdown was also scheduled to coincide with the period during which there is a marked decline in the recreational usage of the reservoir. Fort Randall, at a reservoir level of elevation 1337.5 feet msl, makes available about 900 MAF of storage space below the base of the Annual Flood Control and Multiple Use Zone for recapture of winter power releases from Oahe and Big Bend Dams. During droughts greater than that of the 1930's, when System storage reserves and System releases are reduced, an additional drawdown of Fort Randall to as low as 1320 feet msl may be scheduled to permit Oahe and Big Bend Dam releases to be maintained near a 15,000 cfs rate during the winter period.

7-12.4. **Other Hydropower Considerations – Annual Oahe Drawdown.** While not as significant (in terms of pool level fluctuation) as the Fort Randall recapture, a similar recapture can occur at Oahe. This recapture is coordinated with upstream Fort Peck and Garrison Dam releases. Oahe recapture may also significantly increase the amount of winter energy generation. During the 4-month winter period, Garrison Dam releases normally are scheduled to be at least 1 MAF more than Oahe releases. The recapture of these upstream releases results in a rise of up to 5 feet or more in Lake Oahe elevation during the winter months.

7-12.5. **System Hydropower Coordination.** Daily, real-time regulation of the System for hydropower purposes is closely coordinated with Western and with regulation of the System for non-hydropower purposes. Detailed advance planning is essential so that releases from each of the System projects for any of the other authorized project purposes may be used to the fullest extent practicable for optimum power production. Daily schedules of power production for each System powerplant are prepared and furnished to Western. Western, in turn, makes such daily changes in the power marketing arrangements as are necessary. Power production orders, which include the scheduled daily generation as well as limits of powerplant loading, are issued directly by the RCC to individual System powerplants. Within the limits of the daily schedules, Western controls the actual hourly loadings of the plants, subject to the limitations imposed by load limits in the power production orders and discharge limits imposed by concurrent reservoir regulation orders schedule by the RCC.

7-12.5.1. The Big Bend and Oahe powerplants are used primarily to follow daily load patterns. In the summer cooling season, Big Bend and Oahe generation is patterned to meet peak electricity demands, which generally occur around 6 p.m. In the winter heating season, their generation is patterned to meet morning and evening peak demands. The Fort Randall, Garrison, and Fort Peck powerplants are also used for peaking, but to a lesser degree. The relative role of each powerplant in meeting required peaking patterns varies with relative water supply available to each powerplant and other regulation factors. The peaking patterns vary through time, primarily in response to such factors as the demand for power and the average release rate through the System. At individual dams, daily power releases are normally adjusted for other project purposes, taking into account; flood control, water conservation, environmental objectives, physical and seasonal constraints, and other factors.

7-13. **Navigation Purpose System Regulation.** Historic System regulation to serve the navigation purpose is detailed in Appendix G of this Master Manual. Service was provided to navigation on the lower Missouri River during the years that Fort Peck was regulated as an individual project. With the construction and filling of additional System projects, this service was expanded. Full-length (8-month) seasons were first initiated in 1962 and have continued except in years when flow reductions were required during extended droughts. Navigation service flows have been provided since June 1967. Navigation on the Missouri River occurs from Sioux City to the mouth near St. Louis. Commercial traffic has ranged from as high as 3.3

million tons in 1978 but has declined in recent years to just over one million tons. In 1999, total commercial traffic moved by barge reached a record peak of 9.25 million tons. Commercial tonnage, not including sand, gravel, and waterway materials, accounted for 1.58 million tons. The Missouri River Bank Stabilization and Navigation Project is authorized to provide a 9-foot deep by a minimum of 300-foot wide navigation channel. Downstream flow support is provided to meet many of the Congressionally authorized purposes, which includes navigation. Navigation flow support is provided to maintain an 8 to 9-foot depth in the navigation channel depending on the amount of water stored in the System, according to the criteria presented in Table VII-2. Table G-3 in Appendix G shows the navigation tonnage previously discussed.

7-13.1. **Navigation and Other Downstream Support Considerations.** Frequent groundings are often experienced during the early portion of the navigation season. These are believed to be due to a combination of cold water temperatures and because it does take some time for the channel dimensions to adjust from the lower winter flows to the higher navigation and downstream support flows. To alleviate this situation, when appropriate, based on water supply, downstream flow support releases at the beginning of the season may be scheduled for a short period at a level of up to 5,000 cfs higher than the service level requires, to provide channel conditioning provided System storage levels at the time are adequate.

7-13.1.1. Day-by-day regulation of the System to support navigation requires forecasts of inflow to various reaches of the Missouri River below the System. From these forecasts and current flow targets, the control point (either Sioux City, Omaha, Nebraska City, or Kansas City) is determined daily. Anticipated traffic or the absence of traffic at the control points will also have a bearing on the control point selection. For this reason, the RCC will continuously monitor traffic movement on the Missouri River. After selection of the control point, releases from the System are adjusted so that, in combination with the anticipated inflows between the System and the control point, they will meet the target flow at the control point.

7-13.2. **System Downstream Flow Support.** The System releases required to meet the minimum and full-service targets vary by month in response to downstream tributary flow, as shown on Table VII-10. These values will be updated as additional data are accumulated and when a significant change in these values occurs. A re-analysis of the average monthly Gavins Point Dam releases needed to meet navigation service requirements was completed in 1999. As part of this study, the relationship between annual runoff upstream of Sioux City and the average Gavins Point Dam release required for the navigation season was analyzed. That study showed that generally more water was needed downstream to support navigation during years with below-normal upper basin runoff than during years with higher upper basin runoff. Regulation studies performed since 1999, therefore, use two levels of System release requirements; one for Median, Upper Quartile, and Upper Decile runoff scenarios and another for Lower Quartile and Lower Decile scenarios. An examination of the data presented in Table VII-10 reflects that, early in the season, the flow target is at Sioux City with adequate downstream tributary flows to meet flow targets. Normally, as the runoff season progresses, downstream tributary flows recede or cease during the summer, and the flow target moves from Sioux City to Nebraska City and eventually to Kansas City. This requires higher flow support as the season progresses through the summer. Often the target moves upstream during the fall, when higher downstream tributary flows return. This seasonal tributary flow pattern is reflected in the Gavins Point Dam release data presented in Table VII-10. These releases are the average monthly values during the period studied for the various runoff conditions and do not reflect the maximum and minimums required during that month to meet flow targets. Actual regulation requires daily adjustments to fully serve the Congressionally authorized project purpose of navigation. Studies conducted for the ESA consultation in the spring of 2003 concluded that 30,000 cfs would be needed to provide a 90 percent assurance of meeting minimum service flow targets in July and August. That study used all runoff data from the period of analysis (1898 through 1997).

Table VII-10
Gavins Point Releases Needed to Meet
Downstream Target Flows for Indicated Service Level
1950 to 1996 Data
(Discharges in 1,000 cfs)

Median, Upper Quartile, Upper Decile Runoff

Service Level	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full-Service	26.7	28.0	27.9	31.6	33.2	32.6	32.0	31.1
Minimum-Service	20.7	22.0	21.9	25.6	27.2	26.6	26.0	25.1

Lower Quartile, Lower Decile Runoff

Service Level	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Full-Service	29.8	31.3	31.2	34.3	34.0	33.5	33.1	31.2
Minimum-Service	23.8	25.3	25.2	28.3	28.0	27.5	27.1	25.2

7-13.3. **Navigation Service Disruptions.** The level of service to navigation can be affected by release restrictions at Gavins Point Dam for the tern and plover nesting season. Release restrictions were first implemented in 1986 to preserve nesting habitat and not inundate nests or birds that could not yet fly. At times during the release restriction period, navigation target flows could not be met because tributary flows are declining in July and August and flows cannot be augmented by increased releases from Gavins Point Dam beyond the maximum release established prior to tern and plover nesting. Generally, release restrictions to protect the birds are lifted in mid-August when the young birds are able to fly and leave the area. Beginning in 1995, releases from Gavins Point Dam were adjusted in early May, when the terns and plovers began to initiate nesting. The release rate was based on an assessment of flows needed to support navigation in July and August. The resulting release prevented the inundation of nests and chicks by not requiring increased downstream support later in the summer.

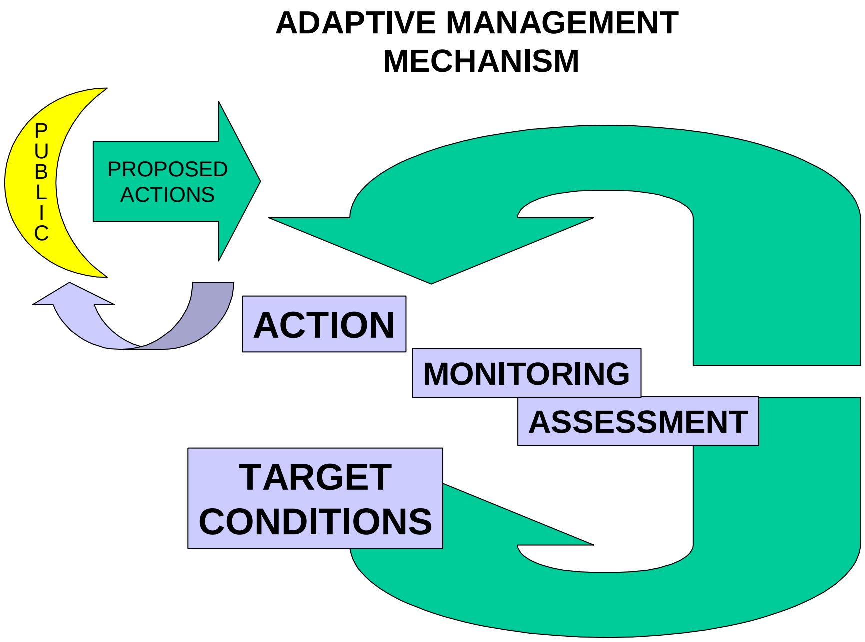
7-13.3.1. High lower Missouri River flows can also disrupt navigation. The river is generally closed to navigation when stages become so high that towboat prop-wash and the wake from the tows can damage the Missouri River levees. In the flood of 1993, the Missouri River was closed for navigation for 7 weeks due to high flows between Kansas City and St. Louis. The U.S. Coast Guard has the responsibility of officially closing the Missouri River. The Corps and the Coast

Guard coordinate this closing and reopening so that significant impacts can be minimized both to the levee system and to the navigation industry. During both the 1987-93 drought and the current drought, navigators experienced hardships and lost revenues due to both reduced Gavins Point Dam releases and shortened navigation seasons, including disruptions caused by court-ordered actions and threatened and endangered species operations. Table G-3 provides the season lengths and tonnage on the Missouri River since the System filled in 1967.

7-14. **Adaptive Management.** The Corps has implemented some System regulation changes via an Adaptive Management process for many years. The Corps, in implementing the CWCP described in this manual, will continue the use of the Adaptive Management process. Adaptive Management is not a new concept; but rather, commonly used throughout the world to help shape resource management decisions, policies, and approaches. The process involves recognition that all is not known about the impacts, both positive and negative, of changes in System regulation. It also recognizes the likelihood that physical conditions may change in the future, and allows flexibility to meet the challenges of those changed conditions. For example, the database of information on the complete life cycles and behaviors of the threatened and endangered species or their requisite habitat needs throughout their life cycles grows constantly. Adaptive Management is an overall strategy for dealing with change and scientific uncertainty. It promotes an environment that allows testing of hypotheses and pursuit of promising change based on sound scientific data and analyses followed by critical monitoring and evaluation.

7-14.1. The Corps recognizes that changes in the operation of the System may impact many river uses and is committed to ensuring that the public is actively involved and well informed of potential changes in System regulation and has the opportunity to comment on those proposed changes prior to any decision on implementation. The adaptive management process will be used to implement changes designed to improve the benefits provided by the System, including benefits to the threatened and endangered species. Decisions regarding actions proposed through the adaptive management process will meet the Corps' treaty and trust responsibilities to the Tribes and conform to all of the applicable requirements of Federal laws including the National Environmental Policy Act, Endangered Species Act and the Flood Control Act of 1944.

7-14.2. **Adaptive Management Process Diagram.** A conceptual diagram of an Adaptive Management strategy is provided below.



7-15. **Drought Contingency Plan.** Regulation of the System during drought was a significant consideration in the development of this CWCP. The System is the largest reservoir system in the United States, serving all authorized project purposes during an extended drought like the 1930's was part of the original objectives of the System. This resulted in the construction of the System with an enormous amount of water normally retained in System storage in anticipation of the onset of extended drought. For this reason, the three upper reservoirs are extremely large compared to other Corps reservoirs, which makes the System so unique. The System was designed to use this stored water during extended drought periods to meet a diminished level of service to all Congressionally authorized purposes except flood control. As such, no separate Drought Contingency Plan is needed or required for the System, as it is included as part of the CWCP presented in this Master Manual.

7-16. **Flood Emergency Action Plans.** The Omaha District is responsible for the development of Flood Emergency Action Plans for the System. The Omaha District has developed a Contingency Plan for Emergencies for each of the System dams, and these plans are presented as Appendix E of the Operations and Maintenance Manuals for each System project. The action plans were all developed for individual projects and were last updated in 1984. These action plans are available to the RCC and project staff for use should a catastrophic failure be imminent or occur. These action plans are contained in large documents and, as such, are not provided as part of this Master Manual. In addition, the Omaha District has conducted full Emergency Dam Safety Exercises involving all of the larger System dams with expected emergency management partners. The RCC was a participant in these exercises and provided modeling support for System regulation during the exercises. The Fort Peck Dam Safety Exercise was conducted in July 1985, and it simulated an earthquake-related event that involved Federal, State, and local participation. The Garrison Dam Safety Exercise was conducted in August 1987, and it was a flood-related event that involved Federal, State, and local participation. The Oahe Dam Safety Exercise was conducted in September 1992, and it was also a flood-related event with Federal, State, and local participation. These full-scale Dam Safety Exercises have also been augmented by tabletop exercises to train and prepare the staff for emergency situations.

7-17. **Other Considerations.** Other considerations than just serving the authorized System purposes must be served from the System, as needed. Adjustments are made to System regulation at times for downstream construction and to aid in recovering bodies from drowning accidents. Recently, adjustments in reservoir levels or dam release rates to help reintur cultural artifacts and human remains at Tribal burial sites have occurred. Special regulation to determine the effectiveness of moving accumulated sediment below the System projects has also occurred.

7-18. **Deviations from the CWCP.** The deviations from the operational objectives presented in this Master Manual or the following year's AOP final plan are discussed during the AOP process. All significant deviations from this CWCP will be coordinated and approved by the Northwestern Division Commander, who may also coordinate with higher authority. All deviations of significance are modeled and presented to the public through the normal coordination procedures involving public press releases and World Wide Web dissemination. Minor deviations are accomplished by the RCC through coordination directly with the affected parties.

7-19. **Rate of Change in Release.** Releases from the System are generally scheduled on a mean daily basis. A gradual change is important when releases are being decreased and downstream conditions are very wet, resulting in saturated riverbank conditions. The RCC staff is aware that a significant reduction in System releases over a short period can result in some bank sloughing, and release changes are scheduled accordingly when a slower rate of change does not significantly impact downstream flood risk. Overall, the effect of System regulation on streambank erosion has been reduced by the regulation of the System because higher peak-runoff flows into the System are captured and metered out more slowly. Increasing System project releases can be changed more significantly than reductions because streambank erosion due to sloughing is not an issue. Many years of regulation experience have also indicated that a simple transition of releases is normally desirable, when possible.

7-19.1. Two sets of criteria are used that are related to the rate of release change for the System dams. The rate of release change criteria is adjusted from that for a normal situation if a flood control regulation objective is initiated to protect life and property in downstream areas or to respond if an emergency exists either at the project or in the project vicinity that requires rapid release changes. Table VII-11 lists the normal and flood control daily rate of release change criteria for each System project. If a situation presents itself that has not been contemplated or a change greater than that described below is required to meet the operational objectives of this plan, the appropriate change will be made. A rate of release change guideline at Oahe and Big Bend does not apply because the tailwaters empty into either a very short river reach or the downstream reservoir, respectively. Also Oahe and Big Bend experience daily changes of releases in the range of full powerplant capacity as required for System hydropower generation to meet this authorized project purpose.

Table VII-11
Mainstem Project
Maximum Daily Rate of Release Change

Mainstem Project	Normal Increase (cfs)	Normal Decrease (cfs)	Flood Control Increase (cfs)	Flood Control Decrease (cfs)
Fort Peck	6,000	3,000	9,000	12,000
Garrison	6,000	3,000	9,000	12,000
Oahe	N.A.	N.A.	N.A.	N.A.
Big Bend	N.A.	N.A.	N.A.	N.A.
Fort Randall	10,000	6,000	12,000	17,000
Gavins Point	8,000	4,000	10,000	15,000

7-19.2. While Table VII-11 shows the maximum daily decrease is 4,000 cfs per day at Gavins Point Dam during a normal situation, this assumes no change in tributary flows downstream. If tributary flows in the reach just downstream of a System project are increasing or decreasing, the actual project release increase or decrease can be based on the combination of tributary flow change and release change to provide the same result downstream. For example, if reach increase of tributary flows of 5,000 cfs were forecasted or experienced at gaging locations in the reach just below Gavins Point Dam and the System were in a normal situation, Gavins Point Dam releases could be reduced by 9,000 cfs per day (5,000 cfs more than the 4,000 cfs shown in Table VII-11) to obtain the same downstream result on the Missouri River as would occur with no tributary flow changes and a release change of 4,000 cfs.

7-20. **Mainstem System Physical Constraints.** The physical constraints of the System are relatively minor with a few exceptions. These constraints are discussed in the following paragraphs.

7-20.1. **Fort Peck – Emergency Flood Tunnels.** The three largest System projects have flood control tunnels that served as outlets when the project embankments were constructed. The flood control tunnels at Fort Peck Dam consist of two 24’ 8” diameter concrete-lined tunnels. The regulation of flow through these tunnels is provided by the operation of a cylinder gate in the tunnels, which also have upstream emergency gates. The use of the flood control tunnels has revealed many operational problems and resulted in high maintenance costs. The operational problems consist of entrained air, cavitation, gate vibration, violent surging, loud noises, and gate icing. The flood tunnels are considered unreliable for the prolonged discharge of water from Fort Peck Dam. The emergency gates consist of cable-suspended, tractor gates, which have never been tested under full flow emergency gate closure conditions. A high probability exists that the emergency gates would not close under full flow conditions, and considerable risk would be associated with any attempt to close these gates under design conditions.

7-20.2. **Fort Peck – Emergency Spillway.** The emergency spillway consists of a gated, overflow weir, with a net crest length of 640 feet; a 5,000-foot long, trapezoidal-shaped, concrete-lined chute; and a 70-foot deep, downstream cutoff wall. The spillway was not provided with an energy dissipation structure. Concerns over the use of the emergency spillway under higher flows consist of the potential for uplifting of the concrete slabs on the spillway and enlargement of the downstream scour hole and its impact on the integrity of the adjacent cutoff wall.

7-20.3. **Fort Peck – Spillway Vertical Lift Gates.** Recent engineering analyses have shown that there should not be any continuous overtopping of the vertical lift gates at Fort Peck Dam other than the wind-induced effects of run-up and setup. A System constraint task item was established following the 1997 flood to evaluate this concern, but the studies have yet to be completed.

7-20.4. **Garrison – Floodplain Development.** The primary regulation constraint for releases from Garrison Dam is an increased water surface at Bismarck and Mandan due to aggradation in the upper reaches of Lake Oahe. The past two decades have resulted in a considerable amount of residential development along both sides of the Missouri River floodplain in the Bismarck, North Dakota area. Flows at and above flood stage will result in a considerable amount of flood damage. The natural Missouri River flows prior to the construction of Garrison Dam were high enough, and the flooding frequent enough, to discourage such floodplain development. When high releases from Garrison are required for flood storage evacuation, local interests will likely express their desires to keep flows through Bismarck below flood stage to reduce the amount of damage in the floodplain near Bismarck. A Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) for the Bismarck area has been completed, but the report has not yet been finalized. The Federal Government does not hold the authority to control local floodplain development.

7-20.5. **Garrison – Spillway Tainter Gates.** Recent engineering analyses have shown that there should not be any continuous overtopping of the tainter gates at Garrison Dam other than wind-induced effects of run-up and setup. This has been an issue when the reservoir nears the top of the Exclusive Flood Control Zone, as it has two times in the past. A System constraint task item was established following the 1997 flood to evaluate this concern, but the studies have yet to be completed.

7-20.6. **Garrison – Spillway Slab.** Use of the Garrison Dam spillway is a concern because of the associated spillway structure uplift pressures. An engineering analysis was completed in 1999 that indicates satisfactory factors of safety are achieved up to a reservoir elevation of 1859 feet msl. Due to the limited amount of data for analysis, a cautious approach should, however, be taken when spillway releases are required. Instrumentation has been installed, and evaluation under higher pools is required to complete the analysis.

7-20.7. **Oahe – Spillway.** The Oahe spillway empties into a downstream earth channel; therefore, when used, it will incur significant downstream erosion and flood damages. There will be some local resistance to using this project feature whenever it is first used.

7-20.8. **Oahe – Spillway Tainter Gates.** Recent engineering analyses have shown that there should not be any continuous overtopping of the tainter gates at Oahe Dam other than wind-induced effects of run-up and setup. A System constraint task item was established in 1998 to evaluate this concern, but the studies have yet to be completed.

7-20.9. **Oahe – High Pool Levels.** There has been considerable concern in recent years regarding the use of the Oahe Exclusive Flood Control Zone for controlling major floods (reservoir level above 1617 feet msl). A Board of Consultants was convened to evaluate the Oahe embankment stability for maximum design pool levels. The primary conclusion of the Board was that *"The dam has sufficient global resistance to operate without restriction to the maximum surcharge pool of elevation 1645 feet. The required safety is provided by the reserve resistance of the potential break-out zone and the three-dimensional restraints."*

7-20.10. **Oahe – Winter Release Rates.** Winter release rates in past years during river ice formation have resulted in minor street flooding in the cities of Pierre and Fort Pierre, South Dakota. This flooding has prompted the application of a restriction on releases from Oahe Dam during a period when river ice formation is occurring, which usually coincides with high demands for hydropower production. A project is currently underway to provide a solution to this problem via a combination of purchasing and/or flood proofing homes and/or the purchase of flooding easements for the affected property in Pierre and Fort Pierre floodplains. The completion of this project will allow for more flexibility for winter regulation of Oahe. Completing this Federal project will take several more years.

7-20.11. **Big Bend – Spillway.** The Big Bend project has never used the spillway, however, this is not considered an operational constraint during periods of large flood evacuations. The powerplant can normally pass the expected flows, but a powerplant failure for more than a short period of time could disrupt the transfer of water downstream requiring supplemental spillway flows.

7-20.12. **Fort Randall – Low Pool Levels.** The fall drawdown and winter refill at Fort Randall permits increased energy generation from the System during the winter. Complaints during the late 1960's about the fall regulation of Fort Randall reduced the amount of the normal fall drawdown from 1320 to 1337.5 feet msl. This change in regulation in the early 1970's has reduced overall power benefits. During a very severe drought, Fort Randall reservoir can be drawn down to 1320 feet msl to augment water provided by the upper three, larger System reservoirs.

7-20.13. **Fort Randall – Flood Tunnel Fine Regulating Gate.** The fine-regulating gate at Fort Randall was destroyed in 1975 and has never been replaced. Two gates in Flood Tunnel No. 11 have been modified to dampen gate vibrations and can be used to make fine regulating releases, either individually or in combination with each other.

7-20.14. **Fort Randall – Reduced Channel Capacity.** There has been significant loss of channel capacity in the downstream Fort Randall river reach, such that releases to evacuate accumulated flood storage in 1997 caused flooding to some property located adjacent to the Missouri River. The Niobrara River has been depositing sediments at its mouth (near the upper end of Lewis and Clark Lake), which is causing a loss of conveyance capacity in the river channel in this reach. Restricted downstream channel capacity because of aggradation remains a concern. Also some cabins and residences have encroached onto the floodplain in this reach and were, in some cases, flooded by the 1997 flood evacuation releases.

7-20.15. **Gavins Point – Spillway Tainter Gates.** Steady winter releases from Gavins Point Dam are required to meet minimum downstream flow support targets. The spillway is used to ensure steady releases in the case of a planned or forced hydropower unit outage. In the case of a forced hydropower unit outage, spillway releases are initiated immediately to ensure that a reduction in flows below target levels does not occur downstream. In the winter, lower than planned downstream flows could cause disruption of established downstream river ice cover by a sudden reduction in flows, which could result in an ice jam. Winter operation of the spillway tainter gates has been hindered by ice formation along the tainter gate seals and the backside of the gates from water spraying over the spillway and freezing. Sidewall heater plates have been installed to alleviate the gate seal problem. These have not been tested to date during a significantly cold winter to determine effectiveness of this solution.

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VIII – WATER MANAGEMENT ORGANIZATION

8-01. **Responsibilities and Organization.** This Chapter describes the personnel and coordination necessary to manage the System. The Corps has the long- and short-term direct responsibility for regulating the System. The System has been regulated as a hydraulically and electrically integrated system since 1953 when Fort Randall Dam (the second Mainstem dam constructed) was closed to begin storing water. As each System dam was completed and filled, System regulation procedures were followed and regulation of the new project was immediately integrated into regulation of the System. The System became "full," or filled to the top of all six projects' Carryover Multiple Use Zones in 1967, following a significant 8-year drought (1954 through 1961) in the Missouri River basin. The year 1967 is, therefore, considered the official beginning of System regulation. The following paragraphs describe the responsibilities for the regulation of the System.

8-01.1. **Corps of Engineers.** The Northwestern Division's (NWD) Missouri River Basin Water Management Division (MRBWMD) of the Programs Directorate, located in Omaha, Nebraska, is comprised of a 20-person staff of hydraulic engineers, biologists, information management specialists, program analysts, hydrologic technicians, and support staff. The MRBWMD is comprised of three teams: Reservoir Regulation, Power Production, and the Master Manual Review and Update. The Reservoir Control Center (RCC) is a subset of MRBWM that includes the Reservoir Regulation and Power Production Teams. The Corps' Guidance Memorandum entitled, "Reservoir Control Center", dated March 1972, serves as the document that details the role and responsibilities of the RCC in managing and regulating the System. The RCC was founded in 1954 and was the first RCC established in the Corps. The organization chart for the MRBWMD in the NWD is provided on Plate VIII-1.

8-01.1.1. The Corps constructed the System projects during the period from 1933 to 1966 and is the sole owner and regulator of the six dams that comprise the System. The Chief of Engineers for the Corps has delegated the regulation of this System to the NWD Commander, who provides oversight of the MRBWMD's day-to-day regulation of the System. The RCC, under the supervision of the Deputy Director, Programs Directorate – Missouri River/Chief, MRBWMD (a dual-hatted position), has the direct responsibility of regulating the System and issues daily release and hydropower production orders to accomplish this mission. The operation and maintenance of the System dams and associated structures are the responsibility of the Omaha District of NWD. The Omaha District has staff physically located at the System projects to make the actual gate changes stated on the System project orders developed and sent by the RCC. The System is the largest reservoir system in the United States, based on the amount of water in storage. The Corps has the responsibility to coordinate the regulation of this System, both within and outside of the Missouri River basin. The RCC prepares long- and short-term runoff and streamflow forecasts that are integrated into model simulations to effectively regulate the System, as described in Chapter 6 of this Master Manual. Each individual System project water control manual contains instructions to the dam tender in case of loss of communication for an extended period of time during a significant or catastrophic event. The RCC staff maintains communication with each other and Corps staff at the System projects via cell phones and computers that are available from work, their homes, and while they are on travel status. Maintaining these communication devices ensures that staff can be reached at any hour of any day of the year. Also, there is at least one staff person that physically reports to the RCC, for at least part of the each day of the year. Detailed calling lists are provided to the System projects and Omaha District Emergency Operations staff in case there is a need to contact RCC staff during normal off-duty hours.

8-01.1.2. The two teams within the RCC have the responsibility for regulating the System. The Reservoir Regulation Team in the RCC has the responsibility of running the daily Missouri River streamflow forecast to determine releases (often called the System release) from the lower-most System dam (Gavins Point Dam). This team also forecasts all runoff volumes for both long- and short-range model simulations. Because runoff forecasting is a critical component in the decision process to determine the most effective flood control release rate, the Reservoir Regulation Team has the responsibility of making all individual System project release determinations during significant System flood control operations. The Reservoir Regulation Team also directs and approves the deviation requests from the Omaha and Kansas City Districts for Corps tributary reservoirs and U.S. Bureau of Reclamation (USBR) tributary projects that have Corps-regulated flood control zones. The Power Production Team has the responsibility of intra-System regulation and threatened and endangered species (T&E) coordination relating to System regulation. Intra-System regulation oversight by this team is conducted to respond to widely varying Missouri River basin runoff to meet the operational objectives stated in this Master Manual. It also performs all hydropower related activities.

8-01.1.3. The Master Manual Review and Update Team was formed to oversee the studies and documentation required for the review of the Mainstem System Master Manual that led to this update of the Master Manual. This team also provides program management for, and oversight of, the non-flow Missouri River and tributaries related actions necessary to comply with the Endangered Species Act (ESA). This team has the responsibility to ensure that the overall adaptive management process for both the flow and non-flow ESA-related actions are established and proceed in an effective and efficient manner.

8-01.1.4. **Adaptive Management.** The Corps has conducted System water management within an adaptive management framework for many years. This Master Manual documents the Corps' vision for the future adaptive management process. This process will allow for the review of System water management by Federal and State agencies, basin Tribes, and the public and allow for their input into the implementation of, and changes to, the CWCP. Additional details regarding adaptive management are presented in Appendix I of this Master Manual.

8-02. **System Coordination.** The RCC strives to keep everyone interested in the short- and long-term regulation of the System informed as to the amount of water stored in the System, the outlook for future runoff, and the short- and long-term plans for System water management. As the largest storage reservoir system in the United States with the potential for a wide array of positive and negative impacts, the regulation of this System generates a high level of interest within and outside of the basin. The Annual Operating Plan (AOP) process, developed by the RCC, provides an important tool for the Corps to interact with, inform, and coordinate with the public on a semi-annual basis. Other interests have a need to keep informed of changes and project status of the System on an almost continual basis. Successful regulation of the System to meet the regulation objectives stated in this Master Manual is dependant on a group of well-informed stakeholders and partners providing continual dialog on the effects of actual and proposed System regulation. The following paragraphs detail how this coordination is accomplished.

8-02.1. **Local Press and Corps Bulletins.** The RCC provides monthly and other special press releases concerning the regulation of the System. The NWD Public Affairs Office is responsible for issuing the official RCC press releases.

8-02.2. **RCC Website.** The RCC maintains a public website at the following address: www.nwd-mr.usace.army.mil/rcc. This site contains information concerning System regulation. It includes forecasted reservoir levels and dam releases as well as historic data in both tabular and graphic formats. The website contains user-friendly, clickable maps to observe graphical streamflow and System project data. The National Weather Service (NWS) has the responsibility for issuing streamflow forecasts. While the RCC performs streamflow forecasting at select locations, these results are not available for public dissemination. The NWS forecasts are available as a link from the RCC website. The website contains special news releases regarding closure of the river for navigation during to extremely large flood events, deviations from proposed regulation plans, water control plan information meetings, T&E nesting operations, and other significant items that occur on an unscheduled basis. In addition, the Corps produces numerous reports on a daily basis that provide continual updates of the System's status and regulation changes. These reports are available to the public by either World Wide Web access or email.

8-02.3. **AOP Public Meetings.** The Corps follows a public process as part of the AOP preparation and implementation process for regulating the System. This process involves the development and publishing of a Draft AOP in the fall of each year. The draft AOP forecasts the regulation of the System for various runoff scenarios for the remainder of the current year, plus the following calendar year. Numerous copies of the Draft AOP are mailed to all interested stakeholders in late September. Public meetings are held at three or four sites within the basin, normally in October, to accept comments from the public and provide a forum for discussion on the Draft AOP. Written comments on the Draft AOP are also considered for a period of generally 30 days after the public meeting dates. After considering the comments from the public meetings and any written comments provided during the comment period, appropriate changes are made to the Draft AOP to produce a Final AOP, which is normally made available around the first of the calendar year. In the spring, the Corps again conducts public meetings to provide information on the current hydrologic conditions in the basin and the expected effects of System regulation for the remainder of the year given the most-likely forecast and other possible runoff scenarios. Once again, comments are obtained for fine-tuning the System regulation for the spring and summer. The RCC follows the Final AOP as closely as possible for the remaining year, and the process begins again in August for the next AOP. It should be stated that not all circumstances are covered in the AOP. Even with this public process, flexibility to deviate from the Final AOP is prudent. This flexibility allows the Corps to regulate the System for maximum benefit in an area of the continent where extreme climate changes can and frequently occur.

8-02.4. **National Weather Service Coordination.** The NWS is the official Federal agency responsible for issuing streamflow forecasts to the public. The Corps uses these forecasts in its regulation of the System. The NWS office interface for the RCC is the NWS Missouri River Basin Forecast (MBRFC), located in Prairie Hill, Missouri. The MBRFC has the forecasting responsibility for the entire Missouri River basin. The Corps and NWS share real-time data, U.S. Geological Survey (USGS) measurements and flood information, and forecasts for streamflow and runoff. The RCC provides the MBRFC with System regulation data on a daily basis. The MBRFC integrates the Corps' forecasted System project releases with its short- and long-range streamflow forecasts for the Missouri River. The normal method of data exchange is through web-displayed products or by direct telephone contact, when required. The Corps receives MBRFC forecasts and Multi-sensor Precipitation Estimates (MPE) rainfall radar imagery, as described in Chapter 5, Paragraph 5-01.2.1 for integration into the RCC real-time forecasting models. During years of significant plains snowmelt, additional coordination between the Corps and MBRFC is necessary to assure a proper data exchange between the two agencies for the forecasting of plains snowmelt. In addition, whenever the Corps conducts special reconnaissance surveys of ice conditions on the Missouri River, the obtained information is readily shared with the MBRFC.

8-02.5. **U.S. Geological Survey Coordination.** The USGS is the primary source of data and hydrologic support to the Corps. The USGS obtains streamflow measurement data that it supplies to the RCC in a real-time mode. This prompt delivery of data allows the RCC to meet its mission of managing the Nation's water resources. This effort is conducted through a cooperative stream-gaging program (CO-OP). This CO-OP program covers the 1) maintenance of Data Collection Platform (DCP) stations, 2) measurement of streamflow at select locations, and 3) sediment and water quality sampling at select locations. The RCC has review responsibility for this program but has delegated the implementation of the program to the Corps' Omaha and Kansas City District Water Management staffs. The Districts negotiate separate programs with each state and manage these programs throughout the year. The USGS also conducts specific data collection efforts to support the Corps. For example, it acquired the specific data needed for impacts modeling of groundwater and fish and wildlife effects of alternative water control plans leading to the selection of the CWCP presented in this Master Manual.

8-02.6. **Western Area Power Administration Coordination.** Long-term (monthly) and short-term (weekly) regulation forecasts of energy generation and capability are coordinated with Western Area Power Administration (Western). These forecasts serve an important role in determining when surplus energy is available during high-water years, otherwise referred to as surplus sales, and when firm energy commitments cannot be met during low-water years, otherwise referred to as energy purchases. These forecasts are also used to reflect unanticipated adjustments in project releases, such as flood control regulation and lawsuits that can dramatically alter energy generation schedules. Scheduled and forced outages of the generating units are closely coordinated with Western. Coordination and letters of support from Western are required during the planning and execution of major rehabilitation of the System powerplants.

8-02.7. **U. S. Fish and Wildlife Service Coordination.** The U.S. Fish and Wildlife Service (Service) is the primary Federal agency in charge of administering the Endangered Species Act of 1973 as it relates to protected species in the Missouri River basin. The RCC and Service coordinate extensively on regulation of the System during the nesting season for the endangered interior least tern and threatened piping plover and on other issues relating to the implementation of the Service's "Biological Opinion the Operation of the Missouri River Main Stem Reservoir System, Operation and Maintenance of the Missouri River Banks Stabilization and Navigation Project, and operation of the Kansas River System", dated November 30, 2000 and its December 16, 2003 Amendment to that Biological Opinion. Additional interagency coordination will continue and expand as the adaptive management process evolves.

8-03. **Interagency Agreements.** No permanent Interagency Agreements are in effect with regard to the regulation of the System. A considerable amount of coordination has been conducted between the RCC and the Federal agencies that have missions that are affected by the System. In 2003, the RCC participated in a Memorandum of Understanding (MOU) with the Southwestern Power Administration (Southwestern) with regard to hydropower generation on the Corps' tributary projects in the Kansas City District. The RCC also had an agreement with the USBR from Boise, Idaho, as recently as 1999, for mutual satellite data collection and backup. This MOU was not renewed because each agency had developed Continuity of Operation Plans (COOP) using other sources for data system redundancy. The RCC has an existing agreement with the Great Plains Region of the USBR for the use of System Replacement Flood Control Storage. The agreement concerns the USBR Clark Canyon, Canyon Ferry, and Tiber projects. These three USBR tributary projects contain authorized Flood Control Storage Zones that are regulated by the Omaha District when water is stored in this zone. The RCC has not exercised the option of using this storage since the drought of the 1980's; however, the water control plans for the System and the individual USBR projects describe this storage and how it would be used to enhance overall basin benefits.

8-04. **Commissions, River Authorities, Compacts, and Committees.** The Missouri Basin Survey Commission (MBSC), in a report to President Truman per Executive Order 10318 dated 1953, recommended that a five-member Missouri River Basin Commission be established by Presidential appointment to oversee the water resource development in the Missouri River basin. This commission never came to fruition; however, several committees, some dating from that period, have provided significant guidance to the primary Federal agencies in developing Missouri River basin water resources and in regulating those resource projects in the Missouri River basin. The following paragraphs discuss the roles of those committees in providing information for consideration in regulation of the System.

8-04.1. **Committee History.** This section describes the major committees in the Missouri River basin previously or presently coordinating water resource planning and System regulation guidance to the Corps.

8-04.1.1. **Missouri River States Committee.** On May 21, 1943, eight basin states formed the Missouri River States Committee (MRSC) for the purpose of lobbying and working collaboratively for water resource development in the Missouri River basin. The MRSC worked with the Corps and the USBR to finalize the Pick-Sloan Plan for the Missouri River basin that led to the construction of the final five dams in the System and made the Fort Peck project a part of the System.

8-04.1.2. **Missouri River Basin Inter-Agency Committee.** In March 1945, the Missouri River Basin Inter-Agency Committee (MBIAC) was formed by the Federal Interagency River Basin Committee to facilitate progress on the Pick-Sloan Plan and the Missouri River navigation project. The group consisted of the Corps, USBR, Department of Agriculture, and the Federal Power Commission (FPC). In addition, the MRSC was invited to provide four representatives. The Corps hosted the first meeting on July 19, 1945 in Omaha. The Committee facilitated the sharing of data and information and provided a format for problem solving in the basin. A revised charter was adopted in 1954 to provide improved facilities and procedures for coordination of the policies, programs, and activities of the various Federal departments and the States in water and related land resources investigation, planning, construction, operation, and maintenance. MBIAC had no authority for making policy for water resource development in the Missouri River basin. The MBIAC functioned until June 14, 1972, when its members joined the Missouri River Basin Commission.

8-04.1.3. **Missouri Basin Survey Commission.** On January 3, 1952, President Truman appointed an 11-member Missouri Basin Survey Committee (MBSC) to determine the land and water resources in the Missouri River basin. It also was to provide guidance on the best way to develop the Missouri River basin resources. The MBSC provided a report in 1953 that promoted the formation of a Missouri Valley Authority to regulate and oversee basin water resource development and coordinate the reservoir regulation of the newly constructed projects. As mentioned in the leading paragraph above, this never occurred.

8-04.1.4. **Missouri River Coordinating Committee.** The Missouri River Coordinating Committee was established at the request of the Corps' Missouri River Division Commander in 1953. The Governors appointed representatives to the Committee, usually the State Engineer or the head of the State's water resources agency. In addition, representatives of the nine affected Federal agencies served in an advisory capacity to represent all interests in their state and basin or for their Federal agency. This Committee served to guide the development of the System and collectively suggested changes to the System from 1953 through 1981. In 1981, it was disbanded because it fell under the purview of the Federal Advisory Committee Act. The overall coordination concept was changed because the Committee had become somewhat less effective and some felt that its members did not always represent all of the interests within their respective State or Federal agency. The process adopted at that time to replace the Missouri River Coordinating Committee was the bi-annual AOP public meeting process discussed in Paragraph 8-02.3.

8-04.1.5. **Missouri River Basin Commission.** In March 1972, President Richard Nixon approved a Missouri River Basin Commission (MRBC). Transfer from the MBIAC to the MRBC was completed formally at a joint meeting on June 14, 1972. The thrust of the MRBC in the early years was the completion of several Missouri River basin water resources studies. At the request of the Governors, this group developed a computerized water accounting system for the Missouri River basin in 1979. This group was disbanded in 1981 as a program that had been created under the Water Resources Act of 1965 and transferred its assets to the Missouri Basin States Association.

8-04.1.6. **Missouri Basin States Association.** Another significant committee was the Missouri Basin States Association (MBSA) that was formed in October 1981, following termination of the MRBC. The Governors of the Missouri River basin states formed the MBSA to provide regional coordination of water resource management. The MBSA was governed by a board of directors composed of one member for each of the ten basin states. The Governors generally appointed senior water resource officials to this position. The affected Federal agencies and other interested persons attended the meetings as observers. The primary goal when the MBSA was first formed was to complete some of the Missouri River basin water resources studies. An office was established in Omaha and was funded through a group effort of the members. The MBSA office in Omaha closed on April 1, 1988.

8-04.1.7. **Missouri River Natural Resources Committee.** The Missouri River Natural Resources Committee (MRNRC) was established in 1988 at the request of the Corps' Missouri River Division Commander to consolidate the recommendations from the State biologists and fishery experts. The intent was to better guide the Corps in meeting the operational objectives of the fish and wildlife enhancement purpose. The MRNRC continues to be active in providing guidance and recommendations to the RCC on fishery resource issues.

8-04.1.8. **Missouri River Basin Association.** In 1993, the MBSA changed its name to the Missouri River Basin Association (MRBA) reflecting the inclusion of the basin Tribes in its membership. The MRBA also expanded its role as providing a single location for resolving water resource issues occurring in the basin. Basin coordination and cooperation on water resource issues were the primary goal of the MRBA, which is active today.

8-04.1.9. **Missouri River Basin Interagency Roundtable.** This group was organized in 2001 to promote interagency cooperation among the Federal agencies within the Missouri River basin. The mission is to foster effective communication and coordination among Federal agencies, and, when possible and where appropriate, to communicate to other basin interests with a single Federal voice. The cooperating agencies include, but are not limited to the Corps, National Park Service, U. S. Geological Survey, U. S. Fish and Wildlife Service, U. S. Bureau of Reclamation, Bureau of Indian Affairs, Environmental Protection Agency, Western Area Power Administration, U.S. Forest Service, and the Natural Resources Conservation Service.

8-05. **Non-Federal Hydropower.** All hydropower facilities located either at or in association with the System are Federally owned and operated. No non-Federal hydropower facilities are currently located either at the System projects or on System project lands.

8-06. **Reports.** The RCC prepares several reports to serve as summaries of activities and to communicate to others the current status and proposed regulation of the System. Most reports are available on the RCC website – www.nwd-mr.usace.army.mil/rcc. This website is used for public dissemination of water resource information related to regulation of the System. In addition to the reports shown in Table VIII-1, the RCC prepares technical reports on an as-required basis to provide information and additional guidance in regulation of the System. The RCC prepared post flood reports on System operations for the 1975, 1978, and 1997 flood events. Also, a detailed post-flood report was prepared by the Omaha District as part of the Great Flood of 1993 entitled, "Post-Flood Report, Mississippi River Basin and Tributaries Flooding, 1993." The Omaha and Kansas City Districts' portions of the report are Appendix D and E, respectively. The RCC provided all pertinent information to the Omaha District concerning System regulation for inclusion in this report.

Table VIII-1
Reservoir Control Center Reports

Frequency of Report/Type of Report	Reporting Requirement*
Hourly	
Hourly plots of gages with DCP transmissions in basin – 15 days provided	
Daily	
Daily Bulletin	
Weekly Bulletin	
Monthly Bulletin	
Yearly Bulletin	
Reservoir Summary Bulletins	
Flood Report	
Ice Report (Seasonal December-April)	
Power Production Orders	
Missouri River Streamflow Forecast – 14 days	
Mainstem Release and Energy Schedule	
Weekly	
Reach Runoff Report	
LRS Three-Week Model Simulation	
Weekly Mountain Snowpack Report	
Monthly	
Basin Calendar-Year Runoff	
Monthly Mountain Snow Report (Seasonal)	
Runoff Outlook	(ER Requirement)
Long-Range Monthly Model Simulation	
Project 0168 Monthly Summaries	(ER Requirement)
Monthly Press Release	
Monthly Project and System Energy Summary	
Yearly	
Draft Annual Operating Plan	
Final Annual Operating Plan	
Annual Summary of Actual Operations	
Division Annual Report	(ER requirement, includes District Reservoirs)
Flood Damages Prevented	(ER requirement - RCC provides holdouts and districts provide estimated damages prevented)
Stage Trends Report	
Annual Sediment Report	(ER requirement)
Annual Water Quality Report	(ER requirement)
Cooperative Stream Gage Program	(ER requirement)

* Reports required per Corps Engineering Regulation (ER).

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Appendix A - Historic Floods and Flood Control Regulation Examples

A-01. **Introduction.** This appendix contains information related to the major historic floods in the Missouri River basin. These examples include floods that occurred prior to the construction of the System and since the System was first filled in 1967. Examples of System regulation during flood control are discussed and also included as an example of regulation for a major hypothetical flood that was derived from a combination of several past major floods. Finally, a historic summary of the sizing of the System storage zones and changes that have occurred are discussed.

A-02. **Historic Major Basin Floods Prior to System Regulation.** This section of this appendix summarizes information on the major floods that occurred on the Missouri River prior to System construction. The earliest major flood with information for water management analysis is the flood of 1844. Flood data on this flood and major floods up to the flood of 1960 are discussed in this section.

A-02.1. **Flood of 1844.** This flood, of near legendary proportions, is generally considered to be the greatest known flood in the lower Missouri River basin. From stage records at Kansas City and St. Louis, Missouri, high water marks at Manhattan and Topeka, Kansas and Boonville and Hermann, Missouri, and the precipitation records at Ft. Leavenworth and Ft. Scott in Kansas and Jefferson Barracks in St. Louis, the flood has been traced, and the events leading up to it, have been reconstructed. These events do not differ from those that are recognized today as being conducive to major lower Missouri River basin flooding and include prolonged periods of antecedent rainfall saturating the basin followed by sequential bursts of intense storm rainfall. From May 10 to June 6, 1844, Ft. Leavenworth had 5.77 inches of rainfall and Ft. Scott had 14.34 inches. The normal precipitation for that time period and location is 4.5 inches. This antecedent rainfall apparently saturated the Kansas River basin sufficiently that most of the 4 to 8 inches of additional rainfall that fell in numerous bursts from June 7 through 14 likely became direct runoff. Actual river stages and discharge measurements are not available for this historical event, but the maximum stages and discharges, shown on Table A-1, are believed to be reasonable estimates and have been accepted by most hydrologic investigators. Some evidence exists to indicate that the basin above the System reservoirs probably contributed only a relatively small amount to the 1844 crest flow at St. Joseph, Missouri. A Missouri River down-bound French steamboat captain reported grounding difficulties in the Dakotas with no report of high water until he saw the evidences of a great flood below the mouth of the Platte River. Further mention of a large contribution from the Platte River that year was provided by a wagon train heading west on the Oregon Trail, which reported in its journals a delay while awaiting the passage of a great flood before fording the Platte River.

A-02.2. **Floods of 1881.** The floods of March through April 1881 include the second greatest flood of record on the Missouri River in the Dakotas, and the “June rise” in 1881 was one of the largest of the late spring rises. The flood year of 1881 had the greatest total cumulative runoff volume of record on the Missouri River between Bismarck, North Dakota, and St. Joseph, Missouri. Following a wet year in 1880, the winter of 1880-81 experienced much-below-normal temperatures accompanied by very heavy snows. This resulted in the heaviest known snow blanket on the plains area by the spring of 1881. Spring thaws and ice breakup began in the

Table A-1
Crest Stage and Discharge Data for Major Floods

Station	Miles Above Mouth	Flood Stage (feet)	1952 Floods			1951 Floods			1943 Floods			1903 Flood			1881 Flood			1844 Flood			Highest of Record		
			Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge (cfs)	Date	Stage (feet)	Discharge (cfs)
Williston	1650.2	20	Apr 1	17.8	170,000	Apr 8	16.8	110,000	Mar 28	19.8											Mar 28, 1943	19.8	
									Mar 30	-	204,000										Apr 4, 1930	-	231,000
Elbowoods (a)	1504.0	17	Apr 5	25.2	360,000	Apr 6	16.0		Mar 31	21.1	241,000										Apr 5, 1952	25.2	360,000
						Apr 11	-	94,000															
Garrison (b)	1455.0	1690	Apr 5	1701.6	348,000	Apr 7	1693.6	130,000	Apr	1696.3											Mar 27, 1947	1704.0	
																					Apr 15, 1952		348,000
Bismarck	1377.8	19	Apr 6	27.9	500,000	Apr 4	16.3		Apr 1	22.7					Mar 30	31.6					Mar 30, 1881	31.6	
						Apr 5		130,000	Apr 3	-	282,000										Apr 6, 1952		500,000
Mobridge	1250.6	16	Apr 9	25.1	435,000	Apr 4	14.8	195,000	Mar 28	19.6											Apr 9, 1952	25.1	435,000
									Apr 5	-	282,000												
Pierre	1117.6	15	Apr 10	25.4	440,000	Apr 8	12.3	127,000	Apr 6	19.6	281,000	Jun 25	9.8		Apr	23.0	259,000 (f)				Apr 10, 1952	25.4	440,000
Chamberlain	1012.9	18	Apr 11	25.6	440,000	Apr 8	11.5	113,000	Apr 7	19.3	(e)										Apr 11, 1952	25.6	440,000
Ft Randall (b)	922.0	1250	Apr 12	1258.9	447,000	Apr 8	1246.3	134,000	Apr 8	1252.6											Apr 12, 1952	1258.9	447,000
Yankton	840.4	12	Apr 13,14	15.5	480,000	Mar 28	11.9	134,000	Apr 9	13.6					Apr 5	30.5					Apr 5, 1881	30.5	
									Apr 8	-	282,000										Apr 13,14 1952		480,000
Sioux City	760.0	16	Apr 14	24.3	441,000	Apr 8	13.0	152,000	Apr 10	18.7	212,000	Jul 10,11	12.3		Apr 23	22.5	362,000 (f)				Apr 14, 1952	24.3	441,000
Decatur (b)	715.7		Apr 15	23.3	(e)	Apr 9	16.6	(e)	Apr 11	20.5	(e)										Apr 15, 1952	23.3	
Blair	670.4	19	Apr 17	23.5	(e)	Apr 12	19.0	(e)	Apr 12	21.4	(e)				Apr 24	19.7					Apr 17, 1952	23.5	
Omaha	632.0	19	Apr 18	30.2	396,000	Apr 11	18.2	152,000	Apr 13	22.4	-	Jun 1	14.4		Apr 25	24.6	370,000(f)				Apr 18, 1952	30.2	396,000
									Apr 12	-	200,000												
Plattsmouth (b)	607.5	952.5	Apr 18	961.4	(e)	Apr 11,12	954.5	(e)	Apr 14	957.6	(e)	Jun 1	11.2		Apr 25	957.9					Apr 18, 1952	961.4	
Nebraska City	579.3	18	Apr 18	27.7	414,000	Jun 2	18.5		Apr 14	19.9	181,000				Apr 27	18.1	380,000(f)				Apr 18, 1952	27.7	414,000
						Mar 29		163,000															
Brownville (b)	552.0	15	Apr 17	29.8	(e)	Jun 3	21.5	(e)	Apr 16	19.9	(e)										Apr 17, 1952	29.8	
Rulo	514.4	17	Apr 22	25.6	358,000	Jun 3	21.0	175,000	Apr 17	20.2	(e)										Apr 22, 1952	25.6	358,000
St. Joseph	460.3	17	Apr 22	26.8	397,000	May 3	19.9	198,000	Jun 18	18.5		Jun 2	20.5	252,000(c)	Apr 29	27.2	370,000	Jun	24.5	350,000(e)	Apr 29, 1881	27.2	
									Apr 18	-	154,000										Apr 22, 1952		397,000
Leavenworth (b)	408.2	19	Apr 23	27.6	(e)	Jul 8	20.8	(e)	Jun 19	23.1	(e)				Apr 30	23.1					Apr 23, 1952	27.6	
Kansas City	377.5	22	Apr 24	30.6	400,000	Jul 14	36.2	573,000	Jun 19	29.1		Jun 2	35.0	548,000(c)	Apr 30	27.8	373,000	Jun 16	38.0	625,000(e)	Jun 16, 1844	38.0	625,000 (c)
									Jun 18		336,000												
Napoleon (b)	332.4	17	Apr 24	24.6	(e)	Jul 14	26.8	(e)	Jun 19	22.4	(e)										Jul 14, 1951	26.8	
Waverly	297.2	18	Apr 24	28.1	369,000	Jul 14	28.2		Jun 18	24.4											Jul 14, 1951	28.2	
						Jul 16		549,000	Jun 19	-	310,000										Jul 16, 1951		549,000
Glasgow (b)	226.8	25	Apr 27	32.1	358,000	Jul 17	36.7	550,000	Jun 21	33.3	(e)	Jun 5	32.7(c)		May 3	28.2(c)					Jul 17, 1951	36.7	550,000
Boonville	196.7	21	Apr 27	27.7	360,000	Jul 17	32.8	550,000	Jun 22	28.8	366,000	Jun 6	30.9	612,000(c)	May 3	23.3		Jun 21	32.7	710,000 (c)	Jul 17, 1951	32.8	
																					Jun 21, 1844		710,000 (c)
Jefferson City (b)	143.0	23	Apr 27	26.1	(e)	Jul 18	34.2	(e)	Jun 23	30.1	(e)	Jun 6	33.5		May 4	26.3(c)					Jul 18, 1951	34.2	
Gasconade (b)	103.9	22	Apr 27,28	29.2	(e)	Jul 19	35.4	(e)	May 21	34.2	(e)										Jul 19, 1951	35.4	
Hermann	96.9	21	Apr 28	27.1	368,000	Jul 19	33.3	618,000	May 21	31.1	550,000	Jun 6,7	29.5	676,000(d)	May 4	23.7		Jun	35.6	892,000(d)	Jun 1844	35.6	892,000(d)
Washington (b)	66.8	20	Apr 28	24.4	(e)	Jul 19	31.0	(e)	May 22	28.6	(e)										Jul 19, 1951	31.0	
St. Charles	28.1	25	Apr 29	31.8	(e)	Jul 20	37.3	(e)	May 22	36.6	(e)	Jun 8	36.8	730,000 (c)	May 5	31.6		Jun 27	40.1	900,000 (c)	Jun 27, 1844	40.1	900,000 (c)

Note: Stages are from gage readings reported by the U.S.W.B unless otherwise noted. Discharge values are those reported or published by the U.S.G.S. unless otherwise noted. Discharge values are given for the flood of 1903, 1881 and 1844 where such estimates are available.

(a) U.S.G.S. gage (b) Corps gage (c) Data from 308 Report (d) Estimated by Kansas City District (e) Stage only station (f) Estimated by Omaha District upper basin in late February and early March while the downstream river was still frozen, resulting in huge ice gorges in the Dakotas. This first rise was checked by a short period of cold weather during which additional precipitation occurred and after which temperatures throughout the plains area rose to well above normal to complete the release of water from snow and ice. The estimated crest stages and discharges of the early spring-type 1881 flood at mainstem locations are shown on Table A-1. The crest stage of 18.5 feet above flood stage at Yankton, South Dakota is the highest known rise above flood stage on the Missouri River and 15 feet higher than any other known stage at that station. This extremely high stage resulted from a tremendous ice jam extending from below Yankton to Vermillion, South Dakota, filling the river channel for a distance of over 30 miles with solid ice rising in places to a height of over 30 feet above the surface of the water. The total flood volume in March and April 1881 has been estimated at approximately 15 million acre-feet (MAF) at Pierre and almost 18 MAF at Sioux City, Iowa. It is known from hydrologic records and gage heights along the Missouri River that the 1881 early spring flood was followed by one of the wettest summers of record. An estimated crest mean daily discharge of 184,000 cfs occurred at Yankton on June 14. An estimated total volume of flood runoff at Sioux City during the March through July 1881 period was more than 40 MAF, which greatly exceeds the volume of runoff for any other year at this location for which records were kept. The severe flood sequence, as reconstructed from available stage records, served as the primary basis for the design of the flood control storage space in the System.

A-02.3. **Flood of 1903.** The severe flood on the lower Missouri River in May and June 1903 resulted from conditions similar to those that caused the great flood of 1844. Excessive rainfall occurred through the lower basin during the first half of May, which saturated the soil and resulted in much-above-normal tributary flows. From May 16 to 31, rainfall occurred almost every day through the lower basin states of Iowa, Nebraska, Kansas, and Missouri. More intense bursts were observed from May 21 to 23. When heavy bursts again occurred from May 28 to 30, the extreme flood developed. Rainfall for the month of May totaled over 17 inches at stations in Iowa, Nebraska, and Kansas. During the period from May 25 to 31, a total of 16.8 inches of rainfall occurred at Abilene, Kansas. Flood flows were of only moderate size in the upstream reaches, but below Omaha, Nebraska, the heavy rains resulted in the most damaging flood experienced to that time through the lower reaches of the Missouri River. Although stages were somewhat lower than in 1844, as shown in Table A-1, increased development of the Missouri River valley resulted in greater damages. This flood was also especially severe on the lower Kansas River and its tributaries. At some locations, maximum record stages were established that have never been exceeded.

A-02.4. **Flood of 1908.** The flood of June 1908 is the greatest ice-free flood known on the Missouri River through Montana and North Dakota. It resulted from general rains in May climaxed by one of the region's greatest rainstorms in June in conjunction with significant mountain snowmelt runoff. Estimated crest discharges during this flood were 155,000 cfs at the Fort Peck Dam site; 240,000 cfs at Williston, North Dakota; 225,000 cfs at Bismarck, North Dakota; 182,000 cfs at Pierre, South Dakota; and 187,000 cfs at Yankton, South Dakota. As the flood crest passed downstream, it coincided with runoff from heavy rainfall in the lower basin. This resulted in extensive flood damage through the downstream reaches, although the crest stages and discharges were not of record proportions.

A-02.5. **Flood of 1927.** Flooding occurred in April 1927 over the lower Missouri River basin largely as a result of rainfall runoff originating in this portion of the basin. Rainfall over the lower basin during March had been considerably above normal while April was the wettest month recorded for so early in the flood season in the lower basin states of Kansas and Missouri. The resulting flood was unique for a flood at this time of the year in that the upper basin made only minor contributions to crest stages and discharges on the lower Missouri and Mississippi Rivers. In the upper Missouri River basin, the high altitude snowpack ranged from about normal to slightly above normal at the end of March, although snow cover over the plains area at this time was virtually nonexistent. During April, precipitation in the upper basin ranged from slightly above to much above normal. This was followed by an exceedingly wet May through all of the upper basin states. In addition to contributing directly to streamflow (maximum floods of record occurred on some tributary streams in South Dakota during May), the heavy April and May precipitation resulted in substantial snow accumulations in the mountainous areas of the basin. Missouri River flows at and above Sioux City during the May through July period were notable for their large volume, high flat crests, and very large recession volumes. The 1927 calendar year runoff above Sioux City (37 MAF adjusted to the 1949 level of water resource development) was the greatest known at that time (records began in 1898). Lower basin runoff during the late spring and summer of 1927 was only moderate and did not compound the flood flows originating from the upstream areas.

A-02.6. **Floods of 1943.** Above-normal precipitation during the winter of 1942-43, augmented by a heavy 4-day snowstorm in the middle of March over the Dakotas, resulted in a near-record snow cover by winter's end in both the northern plains and mountain regions. High temperatures occurring in late March and early April resulted in rapid melt of the plains snow cover over ice-sheathed and frozen ground that, in turn, resulted in a great flood. The formation of ice jams and subsequent progressive release of the water impounded behind them contributed considerably to high crest discharges through both North and South Dakota. Missouri River crest discharges above 200,000 cfs occurred from Williston to Omaha, with peaks near 280,000 cfs from Bismarck to Yankton. As the April flood wave progressed downstream from Omaha, flows receded. Serious damages, however, extended to just above Kansas City, with only minor flooding below that point. The total volume of runoff in March and April was comparatively small, amounting to only 7.3 MAF at Sioux City and 1.8 MAF above Fort Peck, which was impounded in that fairly new reservoir. The March and April flood was closely followed by a flood in May that developed in the lower basin. This flood was generated as a result of heavy rainfall over southeastern Kansas and in the south and central portions of Missouri. Stages in May 1943 were higher than any since 1844 on the Mississippi River at St. Louis, although the crest discharge of 840,000 cfs may have been exceeded in 1903. On the Missouri River at Hermann, a crest discharge of 550,000 cfs occurred on May 21. Crest stages and discharges along the Missouri River in 1943 are shown in Table A-1. During June and July 1943, relatively high discharges again prevailed on the Missouri River in the Dakotas as a result of the melt of the heavy mountain snow cover and above-normal rainfall in the upper basin. A total volume of about 8.2 MAF passed Sioux City during the 2-month period, while 3.76 MAF was stored in Fort Peck. During the same period, the lower basin states also experienced heavy rains that considerably augmented the flow originating upstream and resulted in extensive flooding from Rulo, Nebraska, to the mouth of the Missouri River. A crest of 236,000 cfs occurred at Kansas City on June 18, where the 2-month volume exceeded 15 MAF.

A-02.7. **Flood of 1944.** The March and April period of 1944 was characterized by only moderate rises on the Missouri River above Bismarck, where a crest flow of 136,000 cfs was observed. Heavier snow accumulations through southern North Dakota and South Dakota added materially to the flood volume and increased the crest at Sioux City to 180,000 cfs. Below Sioux City, the April 1944 flood is noteworthy because of the synchronizing of the flood wave as it moved down the river with runoff from general rains through the middle Missouri River basin followed by heavy rains from the lower Missouri River basin. This resulted in crest flows that exceeded any recent record at that time at many of the downstream stations, and even the high flows of 1943 were exceeded on the Missouri at Hermann and on the Mississippi at St. Louis. June 1944 was one of the wettest months of record through the upper Missouri River basin. The combination of excessive rainfall runoff with the melt of the mountain snow accumulation resulted in 10.5 MAF of flow past Sioux City with 2.4 MAF stored in Fort Peck during the June and July period. This represented the greatest volume of runoff originating in the upper Missouri River basin during a comparable late spring period since intensive stream gaging began in 1929.

A-02.8. **Flood of 1947.** In March and April 1947, a flood was caused by a combination of ice jams and a relatively small amount of snowmelt runoff from streams draining portions of Montana, Wyoming, North Dakota, and western South Dakota. Although peak stages were generally less than those of the 1943 flood, Missouri River crest flows at locations in North Dakota exceeded 250,000 cfs and were the highest stages experienced up to that time, exceeding both the estimated 1881 and observed 1943 peaks. High flows on the Missouri River again occurred in June and July 1947 in the Dakotas as a result of heavy rains and runoff from mountain snowmelt. Crest flows increased progressively from 104,000 cfs at Bismarck to 171,000 cfs at Sioux City. In the lower Missouri River basin, the months of March through May 1947 were all wetter than normal, with June being extremely wet throughout the basin. Runoff from this extraordinary series of excessive rains occurring in June was supplemented by the upstream rises to cause the highest stages since 1844 at several stations between Plattsmouth, Nebraska and the mouth of the Missouri River and on the Mississippi River at St. Louis.

A-02.9. **Flood of 1951.** Prior to 1951, the 1844 flood had been the “great” lower Missouri River basin flood. The estimated stages and discharges of that historical flood were generally accepted, although somewhat discounted, for lack of official supporting data. A considerable amount of hydrologic data was assembled prior to, during, and after the rise and fall of the 1951 flood, and these data lend support to the belief that major floods of the magnitude of the 1844 flood were possible. May and June 1951 precipitation over the Kansas River basin was above normal by amounts of 2.66 and 5.58 inches, respectively. The intense rains on July 9 through 13 resulted in sustained and widespread flooding, which was the greatest in recent years. Rainfall accumulated to 18.5 inches at the storm center during this 5-day period and averaged 8 inches over 30,000 square miles of eastern Kansas. Crest stages occurred on the Kansas River and its tributaries within a 4-day period, July 11 through 14. The Missouri River at Kansas City crested on July 14. Fortunately, the crest from the Kansas River coincided with relatively low flows from the upper Missouri River. At Kansas City, the Missouri River remained above flood stage until July 21. The Missouri River crest passed the mouth of the Missouri River on July 21, and by August 1, the lower river fell below flood stage. Peak discharge at the lowermost Kansas River station, Bonner Springs, Kansas was 510,000 cfs on July 13. On the Missouri River at

Kansas City, the peak was 573,000 cfs, and at Hermann, the Missouri River crested at 618,000 cfs on July 19. Other crest stages and discharges are shown in Table A-1.

A-02.10. **Flood of 1952.** The flood of April 1952 in the Missouri River basin was of exceptional magnitude and severity on the Missouri River and most of the tributary streams that join the Missouri River at and above Sioux City. On the Missouri River, flooding was continuous from the Yellowstone River to the mouth. In most of the reach between Williston and the mouth of the Kansas River, a distance of about 1,250 river miles, this flood was the greatest of record. The 1952 flood established record flows throughout and record stages at all locations from the Yellowstone River to the mouth of the Missouri River except for a few isolated locations where previously established record stages resulting from severe localized ice jams were not surpassed. Flooding was generally on all major tributaries of the Missouri River between, and including, the Milk River in Montana and the Floyd River in Iowa, with the exception of the Niobrara River in Nebraska. On many of these tributaries, stages and discharges approached previously established records, and on some, new record stages and discharges were established. Normal winters in the upper Missouri River basin include periods of warm weather sufficiently mild to permit intermittent thawing of the snow cover over appreciable areas. Of particular significance during the winter of 1951-52 was the absence of usual periods of thawing. Thawing periods instead were supplanted by unusually continuous low temperature periods. At the end of March, one of the heaviest snow covers in the history of the upper plains was present. Snow surveys completed at the time of maximum snow accumulation on March 20 indicated a water content in the snow cover ranging from 2.4 inches over about 10,000 square miles in the Yellowstone River basin up to 3.6 inches over much of the Grand River basin in South Dakota. A water content of over 6 inches was present in the lower Grand and Moreau River basins and on the eastern edge of the Big Sioux River basin. The water content of the 1951-52 snow cover was approximately equaled over portions of the basin in previous years but not over nearly as extensive an area. For example, the snow cover over eastern South Dakota was nearly as great in 1950-51 as it was in 1951-52. Similarly, the snow cover over the right bank tributary basins in North Dakota and South Dakota was nearly as great, and over some localized areas even greater in 1949-50, as it was in 1951-52. The heavy snow cover of 1951-52, however, extended over both of these areas and others as well, including the lower Yellowstone River basin in Montana. Severe flooding along the Missouri River began late in March from rapid melting of snow cover in the lower Yellowstone and Little Missouri River basins and over the upstream portions of the Missouri River tributaries in the western Dakotas. With few exceptions, the peak outflows of the western Dakota tributaries were synchronized with the peak flow on the Missouri River. Coincidence of tributary outflows was, in large part, due to release of tributary water that had been ponded behind ice jams formed against the solid ice cover of the Missouri River. Throughout North Dakota, movement of the floodwater downstream was hampered by successive ice jams, which greatly increased stages and discharges. The Missouri River crested at Williston on April 1, with a peak stage and discharge below previous highs of records. At Elbowoods, North Dakota, below the mouth of the Little Missouri River, the flood crested on April 5, establishing a record stage of 25.2 feet and discharge of 360,000 cfs. The flood crest occurred on April 6 at Bismarck, establishing a record discharge of 500,000 cfs. This discharge was more than 75 percent higher than the previous record discharge; however, the record stage established in 1881 was not exceeded. The flood crest reached Mobridge, South Dakota, on April 9, Pierre, South Dakota on April 10, Chamberlain, South Dakota on April 11, Yankton, South Dakota on April 13, and Sioux City, Iowa on April 14. The flood crest moved through most of South Dakota, with peak discharges of 440,000 to 450,000 cfs. An even higher peak discharge of 480,000 cfs occurred at Yankton due to additional tributary inflow. Below Yankton, peak discharges reduced gradually downstream. Throughout South Dakota, past maximum-recorded discharges were exceeded by as much as 72 percent. Past record stages were similarly exceeded at all stations in South Dakota except Yankton, where the record stage was established by the exceptionally severe ice jam below Yankton during the 1881 flood. Below Sioux City, the flood continued to establish new record stages and discharges as far downstream as the vicinity of St. Joseph. The crest reached Omaha on April 18, Nebraska City on April 18, Rulo on April 22, and St. Joseph on April 23. The coincidence of the crest at Omaha and Nebraska City resulted from the valley storage provided by failure of major levee units that reduced the Omaha crest to less than that prevailing at Nebraska City on April 18. At St. Joseph, the peak discharge exceeded the previous high discharge of record, but the record stage established during the 1881 flood, although approached, was not exceeded. Below St. Joseph, the flood did not equal previously established record stages or discharges. Throughout the entire reach from St. Joseph to the mouth, however, the 1952 flood continued to be a flood of major proportions. Crest stages and discharges that occurred during the 1952 flood are tabulated in Table A-1. The flood of April 1952 was strictly a plains snowmelt flood, due entirely to runoff from melting of the winter's accumulation of ice and snow over the plains areas of the upper basin. The great magnitude of the flood was due to several factors that include the unusual areal coverage of the accumulated plains snow cover, the high water content of the snow cover at the time melting began, the rapidity with which melting took place, the frozen conditions of the ground, and the presence of an ice layer beneath the snow cover that resulted in a very high percentage of the snow's water content reaching the stream channels as runoff. Rainfall over the basin prior to and during the flood period was light, and runoff from rainfall did not add to the flood discharges.

A-02.11. **Flood of 1960.** The 1960 plains-area snowmelt flood was the first major flood occurrence since integrated System operations began in 1954. Fort Randall Dam was closed in July 1952, Garrison Dam in April 1953, and Gavins Point Dam in July 1955. All of these dams, in addition to Fort Peck Dam, contributed to the prevention of downstream flood damages. Snow accumulations during the winter months prior to the flood were very large, particularly over the plains areas of South Dakota, western Iowa, Nebraska, and Kansas. Melting of this snow in late March and early April caused record high floods on some tributary streams in the area and general flooding along the Missouri River from the mouth of the Platte River in Nebraska downstream. Inflows to the System were particularly large downstream from Oahe Dam. In the process of controlling the flood, Gavins Point rose 0.7 of a foot into the surcharge pool, overtopping the spillway tainter gates. Outflows from Fort Randall Dam contributed less than 1,000 cfs; however, high inflows between Fort Randall and Gavins Point Dams required releases of 32,000 cfs from Gavins Point Dam. System storage gains during late March and April were about 5 MAF. Stages on the lower Missouri River were as much as 8 feet above established flood stages, resulting in damages of approximately 17 million dollars. Without the regulation provided by the System reservoirs that were already in place, crest stages would have been about 5 feet higher throughout the flooded area. The unregulated crest flow at Gavins Point

Dam was estimated to be 210,000 cfs, which compares to the actual maximum release of 32,000 cfs. Flood damages prevented by those System reservoirs in place and local protective works were estimated to be in the $200 million range.

A-03. **Major Floods Occurring Since the System Filled in 1967.** Several major floods would have occurred or would have been much worse had the construction of the System not been completed. This section of Appendix A provides some information on these events and the effectiveness of the System projects in controlling flood damages.

A-03.1. **Floods of 1967.** One flood occurred in the spring of 1967, and a second one was prevented by the System from occurring. During June 1967, intense rains over the lower basin states of Nebraska, Kansas, and Missouri caused severe flooding along many Missouri River tributary streams and along the main stem of the Missouri River from the Platte River downstream to the mouth. Missouri River crest stages up to nearly 10 feet above flood stage occurred, and over 500,000 acres of agricultural land were inundated. The failure of 171 local levees during the flood contributed to the flooding. During the last half of June, Missouri River stages were so high that navigation was halted to protect water-soaked local levees from the wakes caused by the towboats. In the Missouri River headwaters areas of Wyoming, mountain snows accumulated at a greater than norma1 rate. By May 1967, many mountain snow courses were reporting record high total snow water contents. During late May and continuing through June, heavy upper basin rains coincided with the melt of this mountain snow. This resulted in the third highest May through July runoff volume of record above Sioux City. The System eliminated all flood damage that otherwise would have occurred through the reach extending from Fort Peck Dam to the mouth of the Platte River. At Sioux City, the regulation effects resulted in a crest discharge reduction of almost 200,000 cfs. Total actual flood damages along the Missouri River amounted to over $125 million. The damages prevented by all Federal reservoirs and downstream Federal levees were estimated at about $600 million, of which over $250 million was credited to the System.

A-03.2. **Flood of 1975.** During 1975, flood runoff from the drainage area controlled by the System exceeded that occurring in any previous year during the period of available record extending from 1898 to 1975. This runoff was the result of the melting of the mountain snowpack and spring and early summer rainfalls in a large area of the upper basin. The March-July runoff volume above Fort Peck was more than 10 MAF, 208 percent of average. Runoff into Garrison during the March-July period was more than 22 MAF, 172 percent of average. Both were record runoffs. The rainfall event of June 18-20 was one of the major upper basin rainfall storms often referred to as the "Great Falls Flood." The center of the storm had rainfall totals of over 14 inches, while a 10,000 square mile area had an average rainfall exceeding 6 inches. A considerable amount of flood damage resulted. In the process of regulating this unprecedented runoff, three of the projects (Fort Peck, Garrison, and Oahe) exceeded previous maximum reservoir elevations while sustained releases from all projects were at higher rates than any previous release. All maximum release rates were well below the flow rates that occurred frequently prior to the regulation of the full System; however, continuation of relatively low outflows for over 30 years of System regulation has adversely affected the downstream channel capacity, primarily due to encroachment upon the downstream floodway (overbank area floods normally inundate). Landowners have cleared and placed under cultivation low-lying floodplain areas adjacent to the river; areas that would have been frequently flooded prior to construction of the dams. Another factor affecting the flood damage potential has been deterioration in the capability of the Missouri River channel to pass flows of a moderate magnitude. For example, at Bismarck a stage of 13 feet reflected a flow of about 90,000 cfs prior to the construction of Garrison Dam in the 1950's. In 1975, flows slightly in excess of 50,000 cfs resulted in a stage of that magnitude. Another effect of the low releases was the growth of the Niobrara River delta below Fort Randall Dam that significantly reduced channel capacity through about a 10-mile reach of the Missouri River above the Lewis and Clark Lake delta. Maintenance of relatively stable flows through the portions of the Missouri River above the Platte River also resulted in considerable recreational development, such as boat docking facilities in low lying areas adjacent to the channel. These effects are recognized in the regulation of the reservoirs. In large flood years, such as occurred in 1975, problems associated with higher-than-normal releases occur.

A-03.3. **Flood of 1978.** The volume of runoff into the System during calendar year 1978 exceeded all annual volumes from 1898 to 1978. Drought conditions persisted through the first half of 1977 but gave way to normal precipitation during the fall. On January 1, 1978, mountain snowpack was 150 percent of normal. Extreme cold persisted through February. By March 1, mountain snowpack was 130 percent of normal and a heavy plains snowpack had also accumulated. The snow covered an extensive area of the plains and was much greater than normal. Water equivalents were generally 2 inches, but several areas were as high as 6 inches. The persistent cold weather prevented any melt of the plains snowpack. Heavy rains occurred both upstream and downstream during March and April. The three significant runoff-producing events during 1978 were the March and April plains snowmelt (10.5 MAF above average or 230 percent of average), May rainfall, and June and July mountain snowmelt. While several of the months were very high runoff months, none exceeded historic maximums. The runoff during 1978 totaled 40.6 MAF. A runoff of this magnitude has a 1 in 100 year chance of occurrence, according to the historic record at that time. System storage was only 51.6 MAF on March 1 due to a below-normal water supply in 1977. The March 1 calendar year runoff forecast for 1978 was 31.2 MAF. Even though System storage was below normal, full-service flows were provided by the beginning of the navigation season. This provided an early evacuation of expected above-normal runoff. During the last half of March, System storage gained 6.9 MAF, a record monthly amount at that time. The maximum daily gain of 0.72 MAF was recorded on March 27, and a maximum weekly gain of 3.9 MAF occurred between March 25 and March 31. System releases were significantly reduced during both March and April due to the large amount of plains snowmelt. By May 1, the forecast was increased to 33 MAF, 135 percent of normal. With the large amount of precipitation, both upstream and downstream, by the last week in May System releases from Gavins Point Dam were increased to 10,000 cfs above full service to provide adequate evacuation of System storage in the flood control zones prior to the following March 1. May's runoff was 6.1 MAF, the second highest for May, exceeded only by May 1975. The runoff accumulated during March through May totaled 20 MAF, 11 MAF greater than average and the highest for this 3-month period at that time. The runoff forecast during June was raised to 37.5 MAF, 150 percent of normal. System releases from Gavins Point Dam were increased to 42,000 cfs. System storage climbed to 68 MAF on July 1, and the runoff into the System during the first 6 months of 1978 was 27.9 MAF, exceeding the previous record of 27.4 MAF established in 1952. System releases were further increased to 48,000 cfs. Higher releases would have been preferred but provision of downstream flood control necessitated that releases be held to 48,000 cfs. System storage peaked at 69.3 MAF on July 23. Runoff was forecasted to be 39.1 MAF on August 1. System releases were maintained at 50,000 cfs during August and September. The System was out of balance with Fort Peck 3.6 feet into its Exclusive Flood Control Zone, and both Garrison and Oahe were slightly below their base of their Exclusive Flood Control Zones (see Chapter VII and Section A-06 for details on System storage zones). System releases were increased to 52,000 cfs on October 9, based on a runoff forecast of 39.3 MAF. The 52,000 cfs System release was maintained until the end of November, when releases were reduced to close the navigation season. On December 1, System storage was at 60.4 MAF. A winter System release of 23,000 cfs was maintained. The total runoff for 1978 above Sioux City was originally shown to be 39.5 MAF but later revised to 40.6 MAF, based on some Gavins Point Dam spillway discharge rating adjustments. Extremely cold temperatures entered the basin during the first week of December, and the Fort Peck and Garrison downstream river reaches froze over. Over $450 million in flood damages were prevented by the System in 1978. Basin conditions in early 1978 represented one of the few times that both a large plains snow and large mountain snow occurred at the same time. The 1978 and 1975 runoff events resulted in many operational studies of the System to determine the best System regulation approach to follow to handle such events. Early releases of a greater-than-required magnitude, or pre-releasing, was established as the best method to provide maximum downstream flood protection and assure System project safety during such events. This event and the 1975 flood event were evaluated in great detail and summary System regulation reports written for future guidance.

A-03.4. **Floods of 1984.** The winter of 1983-84 began with record cold temperatures and a heavy plains snow cover. Over 460 miles of the Missouri River below Gavins Point Dam were frozen over all the way to Jefferson City, Missouri. The first flood of the year occurred in April 1984. A late March snowstorm dropped heavy snow over an area from South Dakota to Missouri. Persistent rains of 2 to 4 inches, resulting in near record stages on the James and Vermillion Rivers, followed this storm. The Missouri River flows in the Gavins Point and Sioux City reaches were the greatest April flows since record keeping began in 1898. System releases were reduced to an average of 15,500 cfs during the month of April, the second lowest on record (1962 was lower). Fort Randall Dam releases were reduced to a record minimum in April to support downstream flood control. Fort Randall reservoir rose to 1363.2 feet msl, the highest since 1972. A considerable amount of downstream flood control damage was prevented in the Missouri River reach from Omaha to St. Joseph. Nebraska City crested at a stage of 19.8 feet, 1.8 feet above flood stage, and the river remained above flood stage for 18 days. St. Joseph and Hermann were above flood stage for nearly 30 days during this event. The second flood of the season resulted from a series of downstream rainfall events that occurred in June 1984. Three separate storms during June on saturated soils resulted in significant runoff and flooding. Some of the events had 11-inch rainfalls in a single storm. In one case, this high rainfall occurred following a week when over 9 inches of rain fell on the same area. Several rivers experienced record flows during June 1984. Those of greatest significance were the James River at Scotland, South Dakota; Vermillion River at Vermillion, South Dakota; Little Sioux at Turin, Iowa; Salt Creek at Greenwood, Nebraska; and Platte River at Louisville, Nebraska. Also, the Big Sioux at Akron, Iowa and the Grand River at Sumner, Missouri experienced their second highest peak flows of record. These were the highest flows and resulting flooding that had occurred in the Missouri River basin since the 1952 flood. The System was regulated to provide maximum downstream flood control. The flood crest was reduced by 61,000 cfs by System regulation. Still much of the runoff occurred in the uncontrolled area below the System. Lake Oahe crested at an elevation of 1618.3 feet msl, which was the highest pool level since the System first filled in 1967 and 0.4 foot higher than the previous maximum in 1975. Garrison crested just below the Exclusive Flood Control Zone as a result of reduced releases in all of the System projects for downstream flood control. Record monthly low releases were set at Gavins Point Dam for April, May, and June. Even with the record low releases, the Missouri River was above flood stage for over a month from Nebraska City to the mouth. Flood damages prevented by the System in 1984 were $203 million dollars. The Missouri River was closed to navigation from June 8 to July 8 in various reaches because of the high downstream flows.

A-03.5. **Floods of 1986**. Runoff above Gavins Point in 1986 was 36.2 MAF, at that time the third highest since 1898 and a greater-than-upper-decile runoff (exceeded only 10 percent of the time). Several floods combined to produce the high runoff in 1986. The first flood occurred in late February and early March 1986, when unusually warm temperatures caused a rapid melt of the plains snowpack that had accumulated over ground that was frozen, which amplified the peaking and volume of runoff. Runoff into Garrison and Oahe during March was the second highest since record keeping began in 1898. Several of the tributaries in Montana and North Dakota nearly reached the record levels established in 1952. The System captured 4.3 MAF of runoff in 21 days. Unregulated flows would have been near 100,000 cfs at Garrison Dam and 150,000 cfs at Gavins Point Dam. The majority of the runoff was captured in the System, but Nebraska City experienced actual peak flows in the 100,000-cfs range from contributions from downstream tributary flow contributions. The unregulated flows without the System, however, would have been 240,000 cfs and caused severe damage.

A-03.5.1. Following that event, runoff from Garrison Dam to Sioux City in May 1986 was the second highest since 1898. Monthly runoffs from the middle Missouri River basin were five times normal. Severe flooding on the James, Vermillion, and Big Sioux Rivers required a significantly below-normal System release from Gavins Point Dam for an extended period of time to provide effective downstream flood control. The large volume of runoff into the System at the same time resulted in Lake Oahe reaching a record pool level of 1618.5 feet msl. Only 1.5 feet of the Exclusive Flood Control Zone remained empty. The James River remained above flood stage for 100 consecutive days from March 19 to June 26. The Missouri River ran bluff to bluff above Sioux City. Stage reductions, ranging from a high of 10 feet at Sioux City (unregulated stage of 34.0 feet) to 7 feet at Nebraska City (unregulated stage of 24.5 feet), were provided by the System during this period. A considerable amount of flood damage was avoided downstream. In September 1986, heavy rainfalls of 7 to 8 inches were reported on Fort Peck and in the Milk River basin during a 24-hour period on September 24 and 25. Inflows increased from 8,000 cfs to 160,000 cfs in one day at Fort Peck, the highest one-day inflow ever recorded at Fort Peck. Garrison inflows got as high as 55,000 cfs and the System completely absorbed the runoff and no flood occurred below Garrison Dam from the heavy rainfall event. Over $15 million in damages were prevented at Wolf Point and Culbertson, Montana and Bismarck, North Dakota. Total flood damages prevented in 1986 were $279.3 million.

A-03.6. **Floods of 1987.** The mountain snowpack accumulation for the winter of 1986-87 was much below normal at 63 and 69 percent of normal in the reaches above Fort Peck and Garrison

Dams, respectively. Total runoff for the year was only 21.3 MAF, which is only 85 percent of normal. Even under such dry conditions, a flood occurred. The plains snowpack was above normal in November, but the warmest winter since the 1930s in Sioux City and Omaha melted the snow from December through mid-February. During the last week in February, the weather changed to cold, and snows and wet conditions prevailed. Over 20, to as much as 30, inches of heavy snow fell in the Bad River basin in western South Dakota during a late February snowstorm. During March, a significant amount of precipitation fell in the form of snow and rain below Gavins Point Dam. March was a record setting month for precipitation at Norfolk and Grand Island, Nebraska and Concordia, Kansas. The warm temperatures during the first half of March ripened the snow. By mid-month, the rains came, causing plains snowmelt runoff. Two separate storms produced 1 to 2-inch rains above Gavins Point Dam over a considerable amount of North and South Dakota. In addition, 2 to 3 inches of rain fell from Pickstown, South Dakota to the confluence of the Grand River in Missouri with the Missouri River. Runoff into Oahe was very high and it reached a maximum of 204,000 cfs. This high inflow was followed by inflows of 170,000 cfs and 147,000 cfs on subsequent days, all of which eclipsed the old daily inflow record of 122,000 cfs. On just one day, March 22, System storage gained 478,000 acre-feet (KAF), a record 1-day System storage increase for the period of 1967 to 1987. Stage reductions downstream were 10 feet at Pierre, 18 feet at Sioux City, 15 feet at Omaha, 9 feet at Kansas City, and 6 feet at Hermann. Several new record stages from Nebraska City to Waverly, Missouri were averted by the flood control provided by the System. Flood damages prevented were $450.5 million in 1987, and all of these occurred in March.

A-03.6.1. A late May flood in 1987 occurred on the lower Missouri River. A 5 to 8-inch band of rainfall, centered on southeast Nebraska, fell in late May. These rains caused the Missouri River to go above flood stage from Plattsmouth to the mouth at St. Louis. Hardest hit areas were the lower Platte River basin in Nebraska and the Nishnabotna River basin in Iowa, which tied its previous record stage set in 1984. Releases from Gavins Point Dam were reduced from 30,000 cfs to 20,000 cfs to help lower downstream river stages after the crests occurred. Because the rainfall occurred so far downstream and so close to the river, no flood damages were prevented. This event demonstrates that the System cannot reduce the impact of all prolonged high, downstream river stages at critical periods.

A-03.7. **Floods of 1993.** The Great Flood of 1993, as it was commonly called, caused a large amount of devastating, downstream flooding that occurred below the System. This flood also provides an example of how quickly the System refilled, or recovered, following a severe 6-year drought. The flood came as a surprise in that the plains and mountain snowpack accumulations were certainly not remarkable. All indications were that the 6 previous years of drought would extend into 1993; however, that was not to be the case. The rains that came during the late spring and persisted all summer and were spectacular in their intensity and duration. The rainstorms followed the same path across the basin repeatedly due to a blocking high-pressure system that persisted off shore near Georgia. References to the rainfall amounts were in feet because the rainfall totals for the summer were so high.

A-03.7.1. The regulation of the System that year was quite simple. Due to the 6-year drought, a great amount of System storage space was available, including all of the flood storage space. The System release was reduced to minimum levels necessary to meet other regulation objectives to maximize downstream flood control. The secondary purpose of refilling the System was accomplished through record low releases while significant rainfall runoff upstream was occurring. The System release averaged only 8,000 cfs during July. The System stored nearly 10 MAF during June, July, and August. The Missouri River was closed for navigation on July 3 and was not opened until August 20. This 57-day closure was the longest since the System became operational in 1967.

A-03.7.2. The flood damages that occurred below the System were very high. The amount of actual damages dramatized the fact that the System provides less flood prevention as the distance downstream increases. Record stages occurred on the Missouri River from St. Joseph to the mouth. Near record stages occurred from Nebraska City to Rulo. Although the resulting damages totaled nearly $12 billion, the flood damages prevented by the System were a record level. The System prevented over $4.4 billion in damages during 1993. A total of $15 billion in damages were prevented for all reservoirs and levees in the Missouri River basin. The most significant portion of the flood damages prevented occurred in the cities of Kansas City and St. Louis, where an overtopping of the urban levees was prevented due to flow reductions provided by the System. The stage reductions by the System were not dramatic but made the difference from the levees overtopping in these two metropolitan areas. The nearly $12 billion of actual damages makes the 1993 flood one of the worst floods in recent history in terms of actual damages. The 1993 flood resulted in a Congressional Report called the Galloway Report, which reported on analyses of alternative floodplain measures (e.g., levee setbacks or no levees), effects on the flood stages, including the floodplain development in the Missouri and Mississippi River basin

A-03.8. **Floods of 1995.** The first of two 1995 flood events resulted from the occurrence of a high plains snow accumulation accompanied by rains in April. The second flood was a result of the late melt of a much-above-average mountain snowpack in combination with heavy downstream precipitation during the melt period. As much as 50 to 60 inches of snow fell in central South Dakota during mid-April. A late April rainfall event added to the flooding problems caused in the basin above Sioux City as some streams were at record stages. The mountain snowpack accumulation up to the normal peak accumulation date in mid-April 1995 was average. Following mid-April, the mountain snowpack increased significantly. As the snowpack runoff was stored in the System reservoirs, releases were below normal during the period and provided downstream flood control. System storage peaked at 68.1 MAF on July 27. Flood damages prevented by the System for 1995 were $1.9 billion, about half of 1993 flood damages prevented. The damages prevented in 1995 were the second largest to date. System regulation during this flood event reduced Missouri River flows by over 110,000 cfs from Bismarck to Pierre. Also, Missouri River flows were reduced approximately 100,000 cfs from Sioux City to Kansas City by System regulation. All locations would have been significantly above flood stage without the System. The peak stages would have occurred in late May or early June as a late-melting plains and mountain snowpack would have combined with significant downstream rainfall events to produce very damaging peak flows. The runoff during 1995 totaled 37.2 MAF above Sioux City, which is 150 percent of normal and the second highest runoff from 1898 to 1995. May 1995 runoff included the second largest May runoff of record, and the June and July runoff totals were the tenth and eleventh greatest from 1898 to 1995. Spillway releases were initiated from Gavins Point Dam on July 24 and the total release rate was

38,000 cfs, which was increased to 40,000 cfs on August 1. Releases were further increased to 54,000 cfs by mid August and held for most of the fall period. Gavins Point Dam releases were eventually increased to 55,000 cfs in November as downstream tributary flows receded. Oahe peaked at an elevation of 1618.7 feet msl, which is 0.2 foot higher than the previous record of 1618.5 feet msl in 1986.

A-03.9. **Flood of 1996.** The 1996 flood event resulted from a major accumulation and melt of late season snowpack in the mountains and heavy precipitation across the upper and lower basin, which occurred several times during and after the melt. The System was scheduled to be, and would have been, at the base of the Annual Flood Control Zone on March 1 had not the largest February runoff of record, 340 percent of normal, occurred. Record System releases were made from February through April to prepare the System for the anticipated snowmelt runoff. March mountain snowpack percentages were 114 percent of average above Fort Peck Dam and 124 percent of average between Fort Peck and Garrison Dams. System releases on April 1 were scheduled at 10,000 cfs above full service. The System release was increased three times during May, reaching 25,000 cfs above full service on June 1. The late season mountain snowpack accumulation, which peaked the first week of May, delayed mountain snowmelt significantly, which increased the total runoff in 1996. Oahe tied a record high reservoir level of 1618.7, which was previously reached in 1995. This level was attained on June 23, following a prolonged cutback in releases in response to downstream flood control regulation. Some of the smaller tributaries below the System, such as the Little Sioux River (32,000 cfs), Monona-Harrison Ditch (10,400 cfs), Boyer River (27,000 cfs), Soldier River (21,400 cfs), and Floyd River (13,300 cfs), had very high peak flows that contributed to cause nearly $13 million in actual damages on the Missouri River between Sioux City and Rulo. During the 1996 flood, System releases were scheduled to evacuate the second highest runoff above Sioux City (37.2 MAF) for the period of record at that time, 1898 to 1996. Flood damages prevented by the System totaled $1.6 billion during 1995.

A-03.10. **Floods of 1997.** The 1997 floods (spring plains snowmelt and mountain snowmelt floods) combined to form the largest Missouri River basin flood event since 1898, in terms of total annual runoff volume above Sioux City. The total annual runoff of 49.0 MAF was almost double a normal runoff and has an estimated frequency of once every 200 years. The 1997 flood event tested the flood control capabilities of the System and serves as a good example of the critical regulation decisions that the RCC must consider during a very large flood.

A-03.10.1. The 1997 flood event, unlike the 1993 flood, was centered above the System; therefore, the System was able to manage and exert significant control over this flood, despite its record volume. Capturing the extremely high runoffs in the System controlled the 1997 flood. The stored water was evacuated at release rates that remained within the downstream channel capacity. A team approach among all Corps offices to solve the problems associated with storing and releasing large volumes of water during significant basin-wide flood control events was more fully implemented in 1997. Full briefings of the Omaha District Dam Safety Committee were provided. In addition, close coordination with the Omaha District Emergency Management office was necessary to assure adequate channel capacity was available by constructing advanced flood protection measures below some projects. A report titled “Summary Report on the

Regulation of the Missouri River Main Stem System During the 1997 Flood" was prepared, and it contains significantly greater detail on this event than is presented here. The report also includes a detailed storm history.

A-03.10.2. The 1997 event really began in late 1996, when a saturated upper basin began experiencing significant plains and mountain snowpack accumulations. This continued through January 1997. The RCC recognized in early January that significant snowpacks were building in both the plains and mountain areas, and appropriate increases in System releases commenced. While the RCC recognized in January that heavy accumulations were occurring, the actual volume or significance of the plains snowpack accumulation was not officially determined. This did not occur until the Corps' Omaha District staff provided snow water equivalent values for the upper plains following a snow survey conducted in March. Of greatest significance is the early pre-release of a considerable amount of water from System storage in preparation for the large volume of runoff that would occur later. Record high monthly System releases occurred from February through December. The rapid snowmelt in combination with the uneven distribution of the plains snowpack required the utilization of a significant portion of the Oahe and Fort Randall Exclusive Flood Control Storage Zones in late March and April. This situation prevailed until water in storage at Oahe and Fort Randall could be balanced between the two upper large reservoirs, Fort Peck and Garrison. This was the first time that it had been necessary to utilize Fort Randall's Exclusive Flood Control Zone to such an extent. Considerable downstream flood control benefits were obtained during the March through April period by not having to increase System releases from Gavins Point Dam above rates that would have caused significant downstream damage. Negative impacts occurred in Lake Francis Case in terms of recreation facility damage and erosion on the embankment face. The embankment had not been protected in all locations to the top of the Exclusive Flood Control Zone. The Fort Randall and Oahe projects entered their respective Exclusive Flood Control Zones in late March, and they remained in this zone until September 1. As a special operation, the Fort Randall reservoir was held at an elevation of 1370 feet msl for an extended period of time to help with riprap placement on the embankment. The 1997 runoff volume during March and April nearly mirrored the previous maximum of 15 MAF that occurred in 1952 before the System was constructed. Having Oahe and Fort Randall reservoirs so high so early in the season with saturated ground conditions was a major concern to the RCC. With the onset of mountain snowmelt, System releases were gradually increased through the summer and fall. This gradual slow increase in System releases resulted in a channel change that had occurred in the high outflow periods of 1975 and 1978. Prolonged high releases from the System created additional downstream channel capacity. The river degradation that occurred after 2 or 3 weeks of releasing water at high rates often resulted in no increase in the river stage as the next increment of flow increase was added to evacuate the unprecedented runoff. In all, over 3 feet of degradation occurred on the Missouri River from 1996 through 1997 in the Sioux City area. This degradation represents over 12,000 cfs of increased channel capacity in this reach. Ultimately, a new maximum record System release rate of 70,000 cfs occurred during November. System storage peaked at 71.7 MAF on July 13, a value only exceeded by the 1975 large rainfall flood event. Flood damages prevented were estimated at $5.2 billion, which is a record amount, exceeding those of the Great Flood of 1993.

A-03-10.3. Unlike the Great Flood of 1993, the 1997 event was significantly controlled by the System. The runoff occurred above the System, except for one downstream runoff event in

April. The actual damages incurred during 1997 were much less than those in 1993. Generally, no large downstream tributary flows occurred during the evacuation period. This was similar to what occurred during flood storage evacuation in 1975 and 1978, the previous high System release flood events. Stage reductions varied significantly and are shown in Table A-2 for the spring (plains snowmelt) and summer (mountain snowmelt) flood events. The RCC approached the 1997 flood similarly to previous floods with the exception of unprecedented above-normal pre-releases from the System. This allowed significant flood control to occur during the peak inflow periods in April and June.

Table A-2
Stage Reductions in
Feet Due to System Regulation During 1997

	Bismarck	Pierre	Sioux City	Omaha	Kansas City	Boonville	Hermann
Spring	3.8	6.6	16.3	13.1	14.4	5.6	8.6
Summer	6.5	8.4	10.7	8.1	8.6	4.8	1.1

A-03.10.4. Because the RCC followed established procedures and developed the overall release plan by modeling the runoff event, the flood was controlled, and maximum flood control benefits were attained, while the risks for significant later System release increases were managed. The 1997 flood event serves as an excellent example of a successful flood control regulation of the System. All past major flood events that have resulted in an accumulation of a large amount of storage within the System project Exclusive Flood Control Zones have resulted in questions regarding the use of this storage zone versus making higher releases to limit its use. There is no reason to believe that future flood events will not prompt the same.

A-03.11. **Flood of 1999.** The 1999 flood was the result of the runoff from a slightly above-normal mountain snowpack, approximately 110 percent of normal, in combination with significant downstream tributary runoff during the April through July period. Annual runoff for 1999 was 31.8 MAF, 124 percent of average. System storage peaked at 65.4 MAF on July 23. The flood damages prevented by the System in 1999 totaled $2.1 billion, of which $2.0 billion were downstream from Rulo. Actual damages incurred in 1999 upstream from Rulo were $13 million. The Corps' tributary reservoirs downstream from Rulo also prevented $2.5 billion in damages during 1999. The large amount of damages prevented was primarily the result of holding back plains and mountain snowpack runoff during the period of April through July, when downstream heavy rains occurred. The Missouri River from Rulo to the mouth was above flood stage at all downstream locations from mid-April through June and again in July. The Missouri River was closed to navigation in three separate months, April, May and July due to high stages from downstream rainfall. Gavins Point Dam releases varied from 28,000 to 32,000 cfs during the period that the Missouri River was at or above flood stage.

A-04. **System Regulation During the Historic Major Floods.** Although Fort Peck was placed into operation in 1937, additional projects on the main stem were not operable prior to the 1950's and early 1960's. Limited System regulation was initiated in 1953 following the closure of the

Fort Randall embankment in 1952 and Garrison in 1953. Gavins Point was closed in 1955, Oahe in 1958, and Big Bend in 1963. Although this completed the embankment closures on the System, regulation of the System was somewhat limited in the early years of regulation by project construction and the completion of real estate activities. In July 1966, installation of all of the present power units was completed, and the following summer the System reservoirs reached their base of the Annual Flood Control and Multiple Use Zones for the first time. Only since that time, have the System reservoirs, therefore, been regulated as a completely integrated System. This section of Appendix A discusses the regulation actions taken in the major floods since 1967 to minimize the flooding on the river reaches within the System and, primarily, those downstream from the System.

A-04.1. **System Storage Accumulation.** Initial fill of the System was accompanied by a period of below-normal runoff from the Missouri River drainage area above the System. Runoff was well below normal during each year of the 8-year period, extending from 1954 through 1961. The cumulative effect of these low-runoff years resulted in the second most severe drought period for the Missouri River basin since 1898. Runoff above the System averaged somewhat above normal from 1962 through the mid-1980's with well-above-normal amounts occurring in some years. The 6-year drought extending from 1987 through 1992, represented a particularly challenging System regulation period. The 1990's represent the highest runoff decade of the past century. As of the writing of this manual (March 2004), the System has been experiencing drought conditions since 2000. Plate VII-2 illustrates month-by-month accumulation of water in the System and its distribution in the individual System reservoirs. As shown on Plate VII-2, the Carryover Multiple Use Zone was first filled in 1967. Since 1967, the volume of water in System storage has generally remained within the Annual Flood Control and Multiple Use Zone that extends from 57.1 MAF to 68.7 MAF (see Chapter VII and the Section A-06 of this appendix on the System storage zones). The typical annual variation of the amount of water in System storage shown on Plate VII-2 reflects the normal accumulation of water in storage during the March through July flood season and normal evacuation of accumulated water to regain this space during the remainder of the year. This plate also shows the years in which an above-normal amount of runoff into the System was stored in the System reservoirs, as indicated by the higher storage levels in those years. In some years, the amount of water in the System was in the Exclusive Flood Control Zone and its surcharge zone, as indicated by those values above 68.7 MAF.

A-04.2. **System Regulation Effects on Streamflow.** The accumulation and evacuation of water in System storage has had a major effect on streamflow below the System. Plate VII-3 presents hydrographs of mean monthly flows at Yankton, which is immediately below Gavins Point Dam, since the System has been fully operational. The flows at Sioux City consist primarily of Gavins Point Dam releases. Unregulated flows are determined at various sites for the purpose of calculating flood damages prevented. Unregulated daily flows are determined by representing the regulated flows adjusted for upstream reservoir effects. The upstream reservoir effects include storage of runoff, an adjustment of reservoir travel time, evaporation from the reservoir surface, and precipitation directly on the reservoirs. The reservoir effects used in the development of unregulated flows include those from major tributary reservoirs and the System projects. The major portion of the reservoir effects results from regulation provided by the System. Unregulated flow development was on a mean daily basis, and only the mean monthly flows are shown on Plate VII-3.

A-04.3. The 1967, 1972, 1975, 1978, 1993, and 1997 hydrographs illustrate the effects of System regulation on substantial flood inflows, as shown on Plates VII-4 through VII-9, respectively. Plates VII-4 through VII-9 also illustrate characteristic patterns of releases from the System. Data to produce similar hydrographs that indicate System regulated versus unregulated flows are stored on the RCC database. The data are available for all years of regulation since 1950 and for other locations within and below the System. Complete write-ups for each year are on file as separate reports in the RCC.

A-04.4. **Flood Control Regulation of 1967 Runoff.** The initial fill of the System was being completed during 1967. Floods were also occurring in the lower Missouri River basin during this same time period. Measured Missouri River flows at Hermann, Missouri exceeded 200,000 cfs from June 13 through July 5, with a crest flow of 372,000 cfs occurring on June 28; the crest stage was over 30 feet, 9 feet above flood stage. In early June, System releases were based on maintaining a navigation service level of 32,000 cfs with corresponding target flows of 28,000 cfs at Sioux City and Omaha, 34,000 cfs at Nebraska City, and 39,000 cfs at Kansas City. By June 12, substantial runoff was forecasted in the lower Missouri River basin. Inquiries to the navigation industry revealed that no river traffic was scheduled for the Sioux City to Omaha reach of the Missouri River; therefore, the Sioux City target was ignored for the period of June 12 to 18, and System release scheduling was based on maintaining target flows at the remaining downstream locations with resultant Sioux City flows expected to be below the minimum service level for navigation. With the expected recession of downstream flood runoff, full-service navigation releases were re-established after June 20. The minimum mean daily release of 14,000 cfs on June 17 nearly coincided when taking into account the 10-day travel time from Gavins Point Dam to Hermann with the 372,000 cfs crest flow at Hermann on June 28. Refer to Plate VII-4 for a graphical display of the regulated and unregulated Gavins Point Dam releases for 1967.

A-04.5. **Flood Control Regulation of 1972 Runoff.** The 1972 System regulation is illustrated on Plate VII-5. This year was one when a large amount of runoff was anticipated from the drainage area above the System. In early March, System calendar year runoff was forecasted to be 115 percent of normal, and, in early April, this forecast was increased to 125 percent of normal. Actual runoff experienced during 1972 above Sioux City, Iowa was 133 percent of normal.

A-04.5.1. **Service-Level Determination.** Regulation during calendar year 1972, based on procedures described in Chapter VII of this manual, was as follows. The service level was defined periodically throughout the year as described in Chapter VII of this manual and as listed in Table A-3.

A-04.5.2. **System Releases.** Gavins Point Dam releases during January, February, and the first half of March 1972 were made at the expanded full-service level of 20,000 cfs due to the large available and forecasted water supply. See Paragraph VII-04.14 of this manual for a detail explanation of expanded full-service level. As indicated in Table A-3, service level determinations on March 1 indicated that flows above the full-service level would be required for

Table A-3
Determination of 1972 Service Level

	March 1	April 1	May 1	June 1	July 1
Tributary Storage[1]	4,450	4,550	4,050	4,350	5,700
Tributary Storage Excess[2]	-1,050	-950	-1,450	-1,150	200
System Storage[3]	59,500	64,600	64,400	66,200	68,500
Forecasted Runoff[4]	24,600	20,100	18,350	14,100	8,650
Water Supply[5]	83,050	83,750	81,310	79,150	77,350
Service Level[6]	40.0	45.0	45.0	46.0	49.0

[1] Accumulated tributary storage in 1000 AF as per paragraph VII-04.13.2 of this manual.

[2] Difference between tributary base storage of 5,500 KAF and accumulated tributary storage as per paragraph VII-04.13.2 of this manual.

[3] Total System storage in 1000 AF.

[4] Forecasted runoff above Gavins Point Dam in 1000 AF from the current date through December 31, as adjusted to the 1949 level of basin development.

[5] Total of tributary storage excess, System storage, and forecasted runoff in 1000 AF.

[6] System service level release in 1000 cfs, as per Plate VI-1.
Per paragraph VII 7-04.13.4, the March 1 level was set at 35.0 kcfs. The April, May, and June levels were all reduced by 5,000 cfs because of seasonal considerations implemented at that time.

storage evacuation purposes. As discussed in Chapter VII, during the beginning of the navigation season when the water supply is ample, a System release rate of 5,000 cfs above the navigation service level can be made to facilitate proper configuration of the navigation channel. Releases during the last part of March 1972 were, therefore, based on a 40,000 cfs service level with downstream target flows of 36,000 cfs at Sioux City and Omaha, 42,000 cfs at Nebraska City, and 46,000 cfs at Kansas City.

A-04.5.3. **Deviation from Water Control Plan.** Strict adherence to the service-level guidelines during flood evacuation periods, which are the same for the CWCP and are outlined in Paragraph VII-04.16 of this manual, would have required System releases based on service levels of 40,000 cfs in April and May and a service level of 41,000 cfs in June. There were some existing issues concerning the channel capacity downstream of Fort Randall Dam that indicated that a service level of 40,000 cfs or greater would result in flood damages. One potential alternative was to decrease the service level from 40,000 cfs to 35,000 cfs. After a considerable amount of study, the RCC concluded that adverse effects would be at a minimum if the 5,000 cfs reduction from the service level was not made. Additionally, the RCC concluded that a relatively uniform release rate at an amount near the downstream channel capacity should be maintained provided that the flood control criteria described in Chapter VII, of this manual could be met. The uniform release supported a service level of 40,000 cfs through most of the April through June period. Reductions to this uniform rate were made at times during this period in order to not exceed the downstream flood control targets of 57,000 cfs at Nebraska City, which is a 45,000-cfs service level plus 12,000 cfs as per Table VII-7.

A-04.5.4. Increasing forecasts of the 1972 water supply along with additional accumulated System storage because of reduced System releases due to downstream runoff resulted in monthly increases in the service level. This resulted in higher adjustments to the System release as the runoff season progressed, as shown in Table A-4. This is a typical pattern with large runoff volumes. Because the runoff potential downstream was reduced after July, the additional release was passed safely below the System with no significant damages. With the 1arge water supply, extended full-service flows were provided at the end of the navigation season that was extended 10 days as an additional water evacuation measure. A winter release rate of 20,000 cfs was maintained during the latter part of November and through December to evacuate a portion of the additional accumulated storage. Plate VII-5 shows the regulated and unregulated releases for 1972 from Gavins Point Dam.

Table A-4
1972 System Regulation

Date	**Volume in MAF**				**Service Level in 1000 cfs**		
	System Storage	**Forecast Runoff**	**Tributary Storage Departure**	**Water Supply**	**Defined[1]**	**Initial[2]**	**Average[3]**
Jan 1, 1972	59.4	25.3	-0.7	84.0	35.0	20.0	19.9
Feb 1	59.2	24.4	-0.9	82.7	35.0	20.0	20.0
Mar 1	59.5	24.6	-1.0	83.1	35.0	20.0	26.1
Apr 1	64.6	20.1	-0.9	83.8	41.0	38.3	39.9
May 1	64.4	18.4	-1.5	81.3	38.0	38.0	37.3
Jun 1	66.2	14.1	-1.1	79.2	41.0	40.0	39.8
Jul 1	68.5	8.7	0.2	77.4	46.0	40.0	43.1
Aug 1	68.0	4.7	0.1	72.8	45.0	45.0	46.1
Sep 1	66.5	3.6	-0.2	69.9	46.0	46.0	46.3
Oct 1	64.4	2.5	-0.4	66.5	50.0	48.0	48.5
Nov 1	62.4	1.4	-0.6	63.2	50.0	48.5	44.5

[1] Based on Plate VII-4 with the 5,000-cfs reduction from March through June applied.
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Chapter VII 7-04.13.4
[3] Actual average monthly System release.

A-04.6. **Flood Control Regulation of 1975 Runoff.** January and February snow accumulations in the mountain areas of the basin were only about 80 percent of normal. Because there was no substantial plains snow cover, runoff during 1975 was expected to be below normal. Winter releases from all projects were maintained at full-service winter levels. The System release rate at Gavins Point Dam was 20,000 cfs. Runoff conditions had not changed substantially by March 1. Full-service navigation releases were maintained through the month of April. During April, mountain snow accumulation increased to 130 percent of normal, a large plains snow accumulated in the North and South Dakota areas, and precipitation was extremely heavy over Montana and western North Dakota. Runoff forecasts made in mid-April indicated that calendar year runoff would likely total more than 20 percent above normal. System releases were increased from the full-service level of 35,000 cfs to 40,000 cfs by mid-May. By mid-June, runoff from mountain snowpack and spring rainfalls in the upper basin resulted in increasing reservoir levels at Fort Peck and Garrison. On June 24, the System release was increased to 50,000 cfs, the maximum System release made since the System had filled in 1967. By mid-June, upstream runoff remained high and it appeared that another System increase, to 55,000 cfs, would be necessary. The basin downstream of the System was, however, experiencing high tributary runoff due to summer storms. The System releases were lowered to 35,000 cfs so as not to contribute to downstream flooding impacts. Meanwhile, heavy rainfalls in the upper basin resulted in a record maximum Fort Peck Dam release rate of 35,000 cfs. System releases were increased and then maintained at 48,000 cfs throughout most of July. Higher releases would have caused problems downstream with interior drainage and lowland flooding. On July 20, the System releases were increased to 60,000 cfs, and downstream private levees were monitored on a constant basis. The System release was maintained at 60,000 cfs through the months of August through November. The System release was lowered to 23,000 cfs by December 10 and maintained at that level through the rest of the year. This serves as an example of a System flood control regulation when the primary inflow resulted from a large rainfall in combination with an accumulation of plains and mountain snowpack late in the accumulation period. This type of runoff season is the most difficult to regulate because no pre-releases are warranted or desired. Plate VII-6 shows the regulated and unregulated flows for 1975. Table A-5 presents the month-by-month progression of the regulation of the 1975 runoff.

Table A-5
1975 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1975	59.7	20.8	-0.9	79.6	35.0	17.2	17.2
Feb 1	59.2	21.1	-1.2	79.1	35.0	17.0	17.1
Mar 1	59.1	20.5	-1.4	78.2	35.0	17.2	19.3
Apr 1	59.9	20.3	-1.5	78.7	35.0	27.5	28.2
May 1	63.0	19.7	-1.6	81.1	37.0	28.0	31.9
Jun 1	66.7	16.2	-1.1	81.8	47.0	35.2	37.5
Jul 1	70.1	11.0	0.3	81.4	62.0	42.5	52.6
Aug 1	71.8	6.4	0.6	78.8	70.0	60.0	60.1
Sep 1	69.7	4.4	0.2	74.3	70.0	60.5	60.5
Oct 1	66.7	3.0	-0.2	69.5	70.0	60.6	61.0
Nov	63.9	1.8	-0.2	65.5	80.0	61.0	61.0

[1] Based on Plate VII-4 with the 5,000-cfs reduction from March through June applied.
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Chapter VII 7-04.13.4.
[3] Actual average monthly System release.

A-04.7. **Flood Control Regulation of 1978 Runoff.** Following a dry year in 1977, the 1978 runoff was forecasted in early January to be approximately 107 percent of normal. System releases in January, February, and the first half of March averaged 16,000 cfs, 4,000 less than full-service releases. During March, mountain snowpack increased to 130 percent of normal, and the plains snow cover increased. Based on this information, the runoff forecast was increased to 126 percent of normal. System releases in April were increased to 24,000 cfs to support downstream navigation. Reservoir elevations continued to rise in the upper three projects. Lower-than-expected April and May runoff and precipitation resulted in the runoff forecast being lowered to the “normal” level. In late May, heavy rainfall and snow events occurred in Wyoming, Montana, and Missouri that altered the runoff forecast. These late May storms caused increased tributary inflows to the Missouri River, both upstream and downstream of Gavins Point Dam. In late May, System releases were increased to 35,000 cfs, full-service releases. May precipitation in Wyoming and Montana ranged from 150 percent to 600 percent of normal. The runoff during the month of May above Gavins Point Dam was the second highest of record for that date, exceeded only in 1975. In June, System releases were increased to 42,000 cfs. Inflows upstream of the System continued to be high in June and July. The total runoff for January through July totaled 27.9 MAF, the highest on record. The previous record for that time period was 27.4 MAF and occurred in 1952. In July, the System release was increased to 48,000 cfs and maintained at that rate. System releases were increased to 50,000 cfs in August and maintained at or near that level through the end of November to evacuate the accumulated System storage, as shown in Table A-6. Total runoff for 1978 was 40.6 MAF, more than 160 percent of normal. Plate VII-7 shows the hydrographs of System regulated and unregulated flows for 1978.

Table A-6
1978 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1978	51.7	24.8	-1.0	75.5	33.0	15.0	15.5
Feb 1	51.4	25.2	-1.1	75.5	33.0	16.0	16.0
Mar 1	51.6	24.3	-1.3	74.6	33.0	16.0	17.5
Apr 1	59.3	20.2	-1.3	78.2	35.0	22.0	21.8
May 1	62.3	16.3	-1.4	77.2	35.0	24.0	27.9
Jun 1	65.9	14.9	-0.6	80.2	43.0	35.0	38.3
Jul 1	68.1	9.5	0.3	77.9	52.0	41.0	44.4
Aug 1	69.1	5.7	0.4	75.2	57.0	48.0	49.6
Sep 1	67.1	3.9	-0.2	70.8	55.0	50.0	50.0
Oct 1	65.5	2.8	-0.3	68.0	60.0	50.0	51.5
Nov 1	62.9	1.6	-0.4	64.1	60.0	52.0	51.9

[1] Based on Plate VII-4 with the 5,000-cfs reduction from March through June applied.
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Chapter VII 7-04.13.4.
[3] Actual average monthly System release.

A-04.8. **Flood Control Regulation of 1993 Runoff.** The Missouri River basin was experiencing a 6-year drought until 1993. This was the first extended drought that had occurred since the System filled in 1967. During this drought, the upper three System reservoirs had reached their lowest levels since 1967. System storage was 14.2 MAF below the base of the Annual Flood Control and Multiple Use Zone at the start of the 1992-93 winter season. The regulation plan was to provide the lowest possible System release, about 12,000 cfs, during the winter to conserve as much water as possible in the upper System projects. The expectation was that, under median runoff, it would take 5 years to refill the System to normal levels. The navigation season opened on March 23, and the minimum-service-level releases were made for navigation purposes. System releases averaged 11,200 cfs in April, 17,600 cfs in May, 17,000 cfs in June, and 8,000 cfs in July. April, May, and July monthly average daily releases were the lowest since the System reached normal operating levels in 1967. The Great Flood of 1993 occurred in July. Heavy and constant rains resulted in substantial inflows into and downstream of the System. The System gained 5.3 MAF of storage during the month of July. Downstream of the System, specifically in the Kansas River basin, even heavier rains forced the RCC to lower System releases to as low as 6,000 cfs so as not to contribute to significant downstream Missouri River flooding that extended from the Platte River to the mouth of the Missouri River. The System essentially refilled by September 1. During the time period that the Missouri River was experiencing flooding, the System release was maintained at the minimum level to support water supply intake requirements downstream of Gavins Point Dam. Table A-7 presents the System regulation summary for 1993. Over $2 billion in flood damages were prevented by the System. The primary damages prevented resulted by reducing flows enough so that the levees in Kansas City and St. Louis were not overtopped. Plate VII-8 shows hydrographs of System regulated and unregulated flows for 1993.

Table A-7
1993 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1993	42.7	20.4	-1.0	62.1	29.0	15.0	13.3
Feb 1	42.8	18.5	-1.2	60.1	29.0	11.0	13.0
Mar 1	43.0	17.7	-1.2	59.5	29.0	11.4	12.3
Apr 1	45.5	15.6	-1.1	60.0	29.0	6.0	11.2
May 1	46.1	13.5	-1.0	58.6	29.0	19.0	17.6
Jun 1	47.6	10.6	-0.1	58.1	29.0	15.0	17.0
Jul 1	50.4	7.6	0.5	58.5	29.0	13.3	8.0
Aug 1	55.8	5.8	0.5	62.1	29.0	7.0	10.8
Sep 1	57.2	4.6	0.4	62.2	29.0	14.0	18.5
Oct 1	57.1	3.1	0.1	60.3	29.0	19.5	21.0
Nov 1	56.9	2.0	0.0	58.9	29.0	21.8	20.1

[1] Based on Plate VII-4 with the 5,000-cfs reduction from March through June applied.

[2] System release at the first[f] of the month, as selected after considering flood control criteria discussed in Chapter VII 7-04.13.4.

[3] Actual average monthly System release.

A-04.9. **Flood Control Regulation of 1997 Runoff.** The regulation of the System during the 1997 runoff year is considered to be the most difficult over the history of the regulation of the System. High runoff conditions were cited very early in the year, and high runoff continued throughout the spring, summer, and fall seasons. The System storage was 57.8 MAF, 0.7 MAF into the Annual Flood Control and Carryover Multiple Use Zone, at the end of 1996. The mountain snowpack measured on January 1 was 181 percent of normal. In addition, heavy snow cover was reported over eastern Montana and the states of North and South Dakota. The January runoff was the highest of record. System releases average nearly 25,000 cfs for the month of January. The higher-than-normal mountain snowpack and plains snow cover continued into February. The February 1 runoff forecast was 33.4 MAF, 136 percent of normal. System releases were increased to average 30,300 cfs for February, exceeding the previous record for February. In March, the mountain snowpack and plains snow cover remained higher than normal for that time of year. The March 1 runoff forecast increased to 35.5 MAF, 144 percent of normal. Average March System releases were 35,600 cfs, a record for March. Melting plains snow during March increased System storage to 64.6 MAF on March 31. The System releases were reduced from 42,000 cfs to 38,000 cfs in response to tributary flooding downstream of the System. Mountain snowpack conditions still remained high in April at 136 percent of normal. The April 1 runoff forecast was raised to 38.5 MAF, 157 percent of normal. Blizzards in the plains area in April and subsequent snowmelt caused the System storage to increase to 67.1 MAF by April 30. System releases were increased early in April from 38,000 cfs to 58,000 cfs, averaging 50,300 cfs for April. System releases were timed and adjusted so as not to coincide with the flood crests of the James and Big Sioux Rivers. These adjustments minimized downstream Missouri River flooding. Mountain snowpack was estimated to be 135 percent of normal on May 1. The May 1 runoff forecast increased to 42.5 MAF, the largest total runoff since record keeping began in 1898. System releases averaged 59,600 cfs for May, 16,000 cfs higher than the next highest average in May 1971. The June 1 runoff forecast was increased to 44.5 MAF due to remaining mountain snowpack and persistent tributary runoff in the plains area of the upper basin. During June, unseasonably warm weather led to rapid melting of mountain snowpack. This snowmelt resulted in record runoff into the System during June. Storage in the System was pushed to a June record high of 71.1 MAF, only 2.3 MAF below the base of the Exclusive Flood Control Zone. Runoff into the System during the first 6 months of 1997 totaled 36.1 MAF, 225 percent of normal. System releases for June remained near 60,000 cfs. High, sustained releases from the System had scoured the channel bed and resulted in a degraded Missouri River channel in some critical reaches. The degradation effect on the channel resulted in an increased channel conveyance capacity. This increase in conveyance capacity allowed the RCC to maintain the high System releases to evacuate System flood storage without causing downstream damages. The July 1 runoff forecast was increased to 46.8 MAF, based on the high runoff in June. System storage crested at 71.7 MAF on July 13. System releases averaged a record 61,500 cfs during July, almost 9,000 cfs higher than the previous record set in July 1975. During August, the extremely high System storage required that System releases increase to 65,000 cfs. The September 1 runoff forecast was increased to 49 MAF, 198 percent of normal. System releases averaged 68,000 cfs for September and October and 70,000 cfs for November to evacuate the System flood storage. The System releases were lowered to 28,000 cfs starting in early December. The total runoff into the System totaled 49.7 MAF, 202 percent of normal.. Plate VII-9 shows hydrographs of System regulated and unregulated flows for 1997, and Table A-8 presents the System regulation for the year.

Table A-8
1997 System Regulation

Date	Volume in MAF				Service Level in 1000 cfs		
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Initial[2]	Average[3]
Jan 1, 1997	57.8	27.2	-0.5	84.5	35.0	21.7	24.9
Feb 1	57.8	29.5	-.07	86.6	37.0	28.0	30.3
Mar 1	59.4	28.3	-1.0	86.7	41.0	35.6	35.6
Apr 1	64.8	23.5	-1.2	87.1	47.0	41.9	50.3
May 1	67.1	20.5	-1.5	86.1	50.0	58.0	59.5
Jun 1	67.7	16.6	-0.6	83.7	50.0	60.0	60.0
Jul 1	71.3	9.0	0.9	81.2	62.0	60.0	61.5
Aug 1	71.1	5.8	0.9	77.8	65.0	60.0	64.4
Sep 1	69.0	4.5	0.6	74.1	70.0	65.0	65.4
Oct 1	66.1	2.8	0.3	69.2	70.0	68.0	68.2
Nov 1	62.8	1.7	0.1	64.6	70.0	70.0	70.0

[1] Based on Plate VII-4 with the 5,000-cfs reduction from March through June applied.
[2] System release at the first of the month, as selected after considering flood control criteria discussed in Chapter VII 7-04.13.4.
[3] Actual average monthly System release.

A-05. **Hypothetical Flood Examples for System Regulation.** The entire flood history of the Missouri River basin, from 1881 to the present, has been used in planning studies of the System. Great historic floods, discussed in this appendix, were examined in as great a detail as the available records would permit. Only since 1929 have sufficient measurements of streamflow been obtained to permit a detailed examination of the effects of individual System reservoir regulation. Prior to that year, synthetic flows had to be derived at numerous locations to illustrate System regulation. The development of the synthetic flows, with corresponding associated uncertainties, was necessary to reconstitute the great floods prior to 1929. This precluded their inclusion in this Master Manual as comprehensive illustrations of System regulation. From the available records, a general examination was made of the past floods, in particular the large floods occurring in 1881 and 1927, to confirm the applicability and reliability of flood control regulation techniques used in this manual. These studies indicated that, with reasonable allowances made for the basin development since the date of flood occurrence, the techniques developed in this Master Manual for the System regulation would provide adequate control, should such floods recur.

A-05.1. **System Regulation During a Hypothetical Flood Sequence of 1944, 1951, and 1952.** Detailed flow records available since 1929 include the greatest known summer flood event downstream from the System, occurring in 1951, and the greatest known spring runoff event originating from the drainage area controlled by the System, occurring in 1952. Detailed records are also available for the large 1944 flood. Flood flows during 1952 occurred during the March and April period, while the 1944 large amounts of runoff originated above the System reservoirs during the June and July period. Examination of the sources of runoff during the 1951, 1952, and 1944 events indicates that a runoff sequence combining the events extending from March 1951 through May 1952 combined with those events extending from June 1944 through March 1945 is not unreasonable. This runoff sequence was created and regulation studies developed to illustrate regulation techniques and their results during this combination of runoff events. The long-range study results of the combined storms of 1944, 1951, and 1952 are shown on Plates A-1 and A-2. Detailed explanation of the data used, the study procedures, and the study results are described in the following paragraphs.

A-05.1.1. **Reach Inflows.** The reach inflows used in the studies were developed from the USGS-published hydrologic record. Plates A-1 and A-2 present the monthly inflow volumes for incremental drainage areas between the dams and between Missouri River gaging stations downstream of the System to Hermann. Missouri River reach inflows, shown for the System portion of the tables in the two plates, are the accumulated reach inflows above Sioux City. While only monthly reach inflows are shown on these plates, it should be recognized that regulation of the System to meet specified flood control and navigation targets requires the use of daily Missouri River inflows for the Missouri River reaches between Gavins Point Dam and Kansas City, Missouri.

A-05.1.2. **Reservoir Evaporation.** The monthly evaporation volumes from each of the System reservoirs during this examined period are also shown on Plates A-1 and A-2. Evaporation depths or rates were assumed to be normal and consist of normal reservoir evaporation amounts, adjusted for the occurrence of normal precipitation on the reservoir surface. The evaporation volume is a function of the evaporation depth and reservoir surface area.

A-05.1.3. **Inflow Adjustments.** The reach inflows that actually occurred at the time of the runoff events required adjustment. Since that time, water resource development of the Missouri River basin has progressed. The inflows shown on Plates A-1 and A-2 represent estimates of the effects of this basin development on the reach inflows, from the time the flows actually occurred to the present time. These estimates are based on data furnished by the U.S. Bureau of Reclamation (USBR) and consist largely of irrigation effects, including storage effects of tributary reservoirs that have a primary function of irrigation. The adjustments for the Nebraska City to Kansas City reach also contain regulation effects of the Kansas River basin reservoirs.

A-05.1.4. **Modified Inflows.** The modified inflows into each of the System reservoirs are shown on Plates A-1 and A-2. The modified inflows consist of observed reach inflows plus the reach inflow adjustment and the release from the dam immediately upstream less the evaporation from the System reservoir receiving the inflow. All reach inflows between Oahe and Fort Randall are assumed to originate below Big Bend Dam, because inflows between Oahe and Big Bend are quite low. Additionally, it was assumed that the Gavins Point and Big Bend projects operate at a constant reservoir level, with modified inflows equal to releases. No modified inflows were tabulated for the Big Bend project due to its short distance from Oahe Dam. At locations below the System, the modified inflows represent the observed reach inflows plus the reach inflow adjustments.

A-05.1.5. **Storage and Reservoir Elevation.** Plates A-1 and A-2 display the end-of-month or the end-of-period reservoir elevation and corresponding storage values listed for the individual

System projects and the System. System storage values listed include the Big Bend and Gavins Point projects' storage volumes.

A-05.1.6. **Releases and Flows.** Plates A-1 and A-2 display the average monthly releases and monthly flow volumes for the System reservoirs and downstream control points. These plates indicate average monthly values; daily flows and releases would indicate a much larger range of values.

A-05.1.7. **Power Production.** Plates A-1 and A-2 display the average power, peak power, and energy production for each period for each of the System projects and for the System. The peak power values displayed on Plates A-1 and A-2 represent values at the end of each time interval.

A-05.1.8. **Service Level.** The service level to be followed by the System at any given time is a function of actual System storage, forecasted runoff above the System, and tributary reservoir storage, taking into consideration the time of the year. Plate VI-1 is used to define this service level. Table A-9 illustrates the service level definition through the 1951-1952-1944 flood sequence period. Forecasted runoff amounts and the departure of total tributary storage from the base level are represented as reasonable values assumed for illustrative purposes.

Table A-9
Service Level Determination for 1951-1952-1944 Flood Sequence

Date	Volume in MAF				Service Level in 1000 cfs	
	System Storage	Forecast Runoff	Tributary Storage Departure	Water Supply	Defined[1]	Selected[2]
Apr 1, 51	59.0	21.5	-1.3	79.2	35.0	35.0
May 1	61.8	17.2	-1.5	77.5	35.0	35.0
Jun 1	62.7	13.6	-0.9	75.4	35.0	35.0
Jul 1	64.5	9.3	0.0	73.8	38.0	38.0
Aug 1	65.3	6.7	-0.3	71.7	41.0	41.0
Sep 1	65.0	5.0	-0.7	69.3	45.0	45.0
Oct 1	64.7	3.5	-0.8	67.4	55.0	55.0
Nov 1	63.3	1.7	-1.0	64.0	60.0	60.0
Dec 1 through Feb 28 . . . . Expanded Full Service						
Mar 1, 52	60.4	34.4	-1.3	93.5	60.0	55.0
Apr 1	61.4	34.0	-1.4	94.0	65.0	60.0
May 1	70.0	23.5	-1.0	92.5	70.0	65.0
Jun 1	70.4	20.1	-0.5	90.0	75.0	70.0
Jul 1	73.6	11.4	-0.2	85.2	75.0	75.0
Aug 1	72.0	5.8	-0.1	77.7	65.0	65.0
Sep 1	69.1	3.1	-0.3	71.9	60.0	60.0
Oct 1	66.3	2.3	-.07	67.9	60.0	60.0
Nov 1	63.8	1.2	-1.0	64.0	60.0	60.0
Dec 1 through Feb 28 . . . . Expanded Full Service						
[1] Based on Plate VI-1.						
[2] Selected after considering flood control criteria discussed in paragraphs Chapter VII 7-04.13.4.						

A-05.1.9. **Definition of System Releases.** System releases are determined on a daily basis during the April through November period of each year, using the RCC streamflow Forecasted Ungaged Inflow (FUI) model described in Chapter 6 of this Master Manual. The conditions of May 15, 1952 are used for illustrative purposes.

A-05.1.10. **Example 1 – Full Service.** A service level of 65,000 cfs was deemed appropriate for this period. The service level of 65,000 cfs would result in Missouri River target flows of 61,000 cfs at Sioux City and Omaha, 67,000 cfs at Nebraska City, and 71,000 cfs at Kansas City. The FUI model was used to route the System releases, tributary flows, and ungaged inflows through the downstream reach. The FUI model indicated that a System release rate of 54,000 cfs would be required to meet the Sioux City target of 61,000 cfs, 50,500 cfs to meet the Omaha target of 61,000 cfs, and 51,000 cfs to meet the Nebraska City target of 67,000 cfs. Additionally, a release of 44,000 cfs would be required to meet the Kansas City target of 71,000 cfs. A System release of 44,000 cfs would result in missed targets at Nebraska City, Omaha, and Sioux City; therefore, the System release of 54,000 cfs is tentatively selected, as it is the lowest System release that meets all four targets. The FUI model indicated that the resultant Missouri River downstream flows from the System release of 54,000 cfs were forecasted to be 61,000 cfs at Sioux City, 64,500 cfs at Omaha, 70,000 cfs at Nebraska City, and 81,000 cfs at Kansas City. The variations of these forecasted flows from the target flows, based on the current service level of 65,000 cfs, are shown in Table A-10. These variations were less than those allowed by flood control considerations specified in Table VII-7; therefore, the 54,000 cfs System release rate was considered appropriate for conditions on May 15, 1952.

Table A-10
Variations from System Releases and Target Flows

Target Location	Forecasted Flow with System Release of 54,000 (cfs)	Target Flow with Full-Service Flow of 65,000 (cfs)	Difference (cfs)
Sioux City	61,000	61,000	0
Omaha	64,500	61,000	3,500
Nebraska City	70,000	67,000	3,000
Kansas City	81,000	71,000	10,000

A-05.1.11. **Example 2 – Full Service.** If forecast variations from the current service level had exceeded those specified in Chapter VII-04.16, reductions in the System release rate would have been required as a flood control measure. For example, if the resultant flow forecast for Kansas City had been 105,000 cfs instead of 81,000 cfs, the variation at this location from the 65,000 cfs service level (Kansas City target flow of 71,000 cfs) would have been 34,000 cfs (105,000 – 71,000), or 4,000 cfs greater than that allowed by the flood control criteria at the current service level. A System release of 50,000 cfs, 4,000 cfs less than the initially selected release of 54,000 cfs, would then be appropriate. The System release of 50,000 cfs would meet the flood control criteria at Kansas City and result in flows greater than full service at Sioux City, Omaha, and Nebraska City. The full-service level of 35,000 cfs, as discussed in Chapter VII-04.14 of this Master Manual, requires target flows of 31,000 cfs at Sioux City and Omaha, 37,000 cfs at Nebraska City, and 41,000 cfs at Kansas City.

A-05.1.12. **Example 3 – Full Service.** If the Kansas City flows from a 54,000 cfs release had been 135,000 cfs, instead of the 81,000 cfs in Example 1, the Kansas City variation from the 65,000 cfs service level (target flow of 71,000 cfs) would be 64,000 cfs (135,000 – 71,000). This is 34,000 cfs greater than allowed by the criteria given stated in Chapter VII—4-16 and Table VII-7 of this Master Manual for full service. Reducing System releases by 34,000 cfs to 20,000 cfs would provide Sioux City resultant flows of 27,000 cfs, which is 4,000 cfs below the full-service level of 31,000 cfs. In accordance with criteria discussed in Chapter VII-04.17, a System release of 24,000 cfs would, therefore, be scheduled to result in Sioux City full-service flows of 31,000 cfs. The resultant Kansas City flow would be 105,000 cfs, or 34,000 cfs greater than the current target level. Because this variation from the target level is less than the criteria for release reductions to the minimum service level (a variation of 60,000 cfs per Chapter VII-04.17 and Table VII-8 of this Master Manual), the 24,000 cfs release is satisfactory.

A-05.1.13. **Example 4 – Minimum Service.** If the resultant Kansas City flow from a release of 54,000 cfs had been 170,000 cfs, instead of the 81,000 cfs in Example 1, the Kansas City flow would exceed the target flow by 99,000 cfs (170,000 – 71,000). This is 69,000 cfs over the full-service flood control criteria (+30,000 at Kansas City) and 39,000 cfs over the minimum-service flood control criteria (+60,000 at Kansas City), as shown in Tables VII-7 and VII-8, respectively. Because it would be impossible to cutback System releases to meet the full-service flood control criteria, the focus is on meeting the minimum service flood control criteria; therefore, as a starting point, a release of 15,000 cfs (54,000 – 39,000) would be considered. The 15,000 cfs release would result in flows of 22,000 cfs at Sioux City, 25,500 at Omaha, 31,000 cfs at Nebraska City, and 131,000 cfs at Kansas City. This release would meet minimum service flow targets at Omaha (25,000 cfs), Nebraska City (31,000 cfs), and Kansas City (35,000), but would not meet the minimum service flow target of 25,000 cfs at Sioux City. The System release would, therefore, need to be increased by 3,000 cfs (25,000 – 22,000) to meet the Sioux City minimum service flow target. The resulting 18,000 cfs System release (15,000 + 3,000) would result in flows of 25,000 cfs at Sioux City, 28,500 cfs at Omaha, 34,000 cfs at Nebraska City, and 134,000 at Kansas City.

A-05.1.14. **Effect of Regulation on Crest Flows.** A comparison of observed crest flows and estimated crests resulting from regulation of the current system of System and tributary reservoirs during the 1951-1952-1944 flood sequence is given in Table A-11. Examination of the crest flow shown in Table A-11 indicates that the System would have had substantial effects on crest flows, particularly those crests resulting from upper basin runoff. Missouri River floods can continue to occur, particularly in downstream portions of the basin. With the storage evacuation requirements, the long travel times involved to lower basin damage centers, and the lack of reliable, quantitative rainfall forecasts for several days in advance, occasions may occur when System regulation augments downstream flood events. A continuing objective of System regulation will be to reduce any such augmentations to the practicable minimum by improving forecasting procedures as technology improves.

Table A-11
1951-1952-1944 Actual and Regulated Flood Crests

	Actual Observed		Regulated by System	
Location	**Crest in 1000 cfs**	**Date**	**Crest in 1000 cfs**	**Date**
	1951 Flood			
Sioux City	152	Apr 8	67	Jun 19
Omaha	152	Apr 11	107	Mar 28
Nebraska City	163	Mar 29	155	Mar 28
Kansas City	573	Jul 24	370	Jul 14
	1952 Flood			
Sioux City	441	Apr 14	65	Apr 11
Omaha	396	Apr 18	85	Apr 1
Nebraska City	414	Apr 19	108	Apr 2
Kansas City	400	Apr 24	120	Apr 24
	1944 Flood			
Sioux City	136	Jul 7	109	Jul 12
Omaha	138	Jun 17	113	Jun 13
Nebraska City	214[1]	Jun 14	180	Jun 14
Kansas City	186[1]	Jun 20	145	Jun 16
[1] Crests at Nebraska City and Kansas City appear inconsistent; however, they are as reported in USGS Water Supply papers.				

A-06. **History of the Sizing of the Storage Zones.** Total storage in the System reservoirs is divided into four storage zones, as discussed in Chapter VII. These four storage zones are the Exclusive Flood Control Zone, the Annual Flood Control and Multiple Use Zone, the Carryover Multiple Use Zone, and the Permanent Pool Zone. The current distribution of the current System storage of 73.4 MAF is described in Chapter VII, but this distribution has changed over the years. Because two of the zones were established for flood control, the history of the distribution of the storage among the four zones is contained in this appendix.

A-06.1. **Original Sizing of the Storage Zones.** The ratio of the gross storage capacity of the System to the annual inflow into the System is unusually high for a major river system and is unprecedented elsewhere in this country. The total System storage is just a little less than the volume of three average years of runoff of the Missouri River above Gavins Point Dam. The large amount of storage results largely from the physical characteristics of the reservoirs and the dam sites. Economic studies at the time of project planning indicated the desirability of the maximum practical site development; consequently, all of the major storage sites, except Fort Peck, were constructed to the maximum level permitted by major relocations from the reservoir areas. The relatively flat slope of the Missouri River valley results in a large storage volume for a given dam height.

A-06.2. **Permanent Pool Zone Sizing.** The top of the Permanent Pool Zones at each System project establishes the normal minimum operating pool level as well as the base of the Carryover Multiple Use Zone (at Big Bend and Gavins Point the base of the Annual Flood Control and Multiple Use Zone). Although competition between the flood control and the other multiple-use purposes was minimal in the establishment of the Permanent Pool Zone levels due to the large amount of storage available, competition between these other multiple uses is apparent, particularly during extended periods of subnormal water supply. At the three larger projects and at Fort Randall, powerplant and surge tank design established runner cavitation limits, and minimum assured peaking capability were based on the selected top of the minimum operating pool. Future lowering of these Permanent Pool Zones would, therefore, appear very unlikely. While drawing down into the minimum pools is less likely with the CWCP than in previous System water control plans, dropping into this storage zone could occur in a drought that was more severe than the drought of the 1930's. The established minimum level at Big Bend and Gavins Point could be lowered, and reservoir levels could temporarily fall somewhat below the minimum rather frequently. Due to the relatively minor amounts of storage space involved and the lakeshore development that has occurred based on the established minimums, any deliberate, long-term lowering of these reservoirs below presently-established minimums is, however, very unlikely.

A-06.3. **Flood Control Storage Versus Carryover Multiple Use Storage Sizing.** Competition between flood control and the other multiple-use purposes existed, to a degree, in first establishing the zonal boundaries between the Carryover Multiple Use Zone and the Annual Flood Control and Multiple Use Zone. The maximum benefit, in the case of flood control, would be to provide sufficient empty storage space to store runoff from flood events of the most remote probability of occurrence. On the other hand, in the case of navigation, power, and other System project purposes, the entire capacity of the System could be used as a Carryover Multipurpose Use Zone to more closely provide full service to these purposes, if a drought like the 1930's were to occur. In view of the magnitude of the potential flood damages in the Missouri River basin, (to urban as well as rural areas and to the extensive transportation and communication facilities in the Missouri River floodplain) the engineers that originally established the volume set aside in each storage zone recognized that the flood control objective of the System should provide for adequate control of a very severe flood that could be expected to recur at only very infrequent intervals. At the time of initial design of the System in the 1940's, it was considered impracticable to establish any single flood event for the System as the "Reservoir Design Flood;" however, the Great Flood of 1881 comprised the most critical flood series of historic record in the Missouri River basin. The 1881 flood, therefore, served, in large measure, as the signature event for establishing System flood control storage allocations and the associated System reservoir release rates, should such an event occur. Allocation of sufficient flood control storage (within the combined Exclusive Flood Control and Annual Flood Control and Multiple Use Zones) to control the 1881 flood event established the base of these two flood control zones and, thus, the volume of storage that could be used for Carryover Multiple Use and Annual Flood Control and Multiple Use purposes.

A-06.4. **Exclusive Flood Control Zone Sizing.** The two upper zones are considered the total System flood control storage space. Within this total flood control space, the level separating the Exclusive Flood Control Zone from the Annual Flood Control and Multiple Use Zone was dictated by specific flood control considerations. Sufficient storage was provided in the

Exclusive Flood Control Zone to control the flood runoff from a significant rainfall event that could occur late in the flood season after the Annual Flood Control and Multiple Use Zone was already filled. Additionally, it was deemed important that sufficient storage remain in the Annual Flood Control and Multiple Use Zone to assure continuation of full service to non-flood control purposes until the following flood season began without an annual draw down into the Carryover Multiple Use Zone. The top elevation of the Exclusive Flood Control Zone at each of the projects, except Fort Peck, are restricted by upstream System dams or cities and, as such, are not subject to change in the future. Sufficient surcharge storage, freeboard space, and spillway capacity are provided at each project to pass the maximum probable flood for each System project while maintaining the individual integrity of the System and its individual projects.

A-06.5. **Summary on Original Zone Sizing.** Allocation of storage in the System was essentially a matter of optimally dividing the storage space made available by site development limitations at the individual projects. A total volume of over 76 MAF initially available in the System below the tops of the Exclusive Flood Control Zones of the individual System projects. Of this total, approximately 18 MAF was considered Permanent Pool Zone storage. This resulted in about 58 MAF of System storage space available for all Congressionally authorized System project purposes. Above the Exclusive Flood Zone lies about 10 MAF of surcharge storage, which is used for regulation of the various spillway design floods, and over 30 MAF of freeboard storage.

A-06.6. **Preliminary Individual Project Storage Zone Allocations.** During preauthorization System planning in 1943 and 1944, studies were made of flood control storage requirements in the System reservoirs as individual units in the basin program. What is now referred to as a Standard Project Flood was not yet developed; the relatively conservative design inflows to the System used in these studies were based on past flood history. Great emphasis was placed on the reconstructed 1881 flood for which records were very sparse and not subject to refined analysis. At the time, no detailed techniques for flood control regulation had been selected. Regulation studies were based on not exceeding specified release rates, with very little consideration of the potential downstream effects of these releases. As a consequence, the System storage required for the control of flood flows varied over a range from approximately 15 to 21 MAF, depending on the criteria and assumptions chosen. These studies determined that, as a result of continued basin water resource development, the required flood control storage space in the System would in time decrease. This was based on a level of basin water resource development that included additional tributary reservoirs that would have flood control functions and on future irrigation and water supply depletions.

A-06.7. As planning and design of the System continued after authorization in the 1944 Flood Control Act, many long-range reservoir regulation studies were prepared, some of which were presented in the Definite Project Reports of the mid to-late 1940's. These early, long-range studies primarily demonstrated performance for three of the four basic purposes, namely navigation, hydropower, and irrigation. Only very general consideration was given to flood control regulation requirements in these early multiple-purpose regulation studies, which were generally limited to a demonstration of monthly flow regulation at Sioux City during the period of record. What was considered at the time of each study to be sufficient flood control storage space, within the range developed in preauthorization planning, was allocated to flood control on an exclusive and seasonal storage basis. The storage allocations used reflected the basic assumptions made at the time of the study and, in retrospect, appear inconsistent to some degree in many cases. Variations between, and limitations of, these early studies resulted for three reasons. First, preliminary System project area-capacity curves were used that later changed. Second, in many cases, no allowances were made for future loss of storage to sedimentation. Finally, different levels of basin water resource development with corresponding differences in irrigation depletions were used and early estimates of future streamflow depletions were subsequently revised.

A-06.8. Some of the early multiple-purpose studies for the partially completed System provided for temporary assignment of greater initial flood control allocations at individual projects to provide sufficient System storage pending completion of all System projects. All of the multiple-purpose reservoir regulation studies of the completed six-project system that were made prior to 1956, however, used a common set of elevations for the base of Exclusive Flood Control and Annual Flood Control and Multiple Use Zones in the System reservoirs, as shown in Table A-12.

Table A-12
Project Zone Levels

Project	Elevation of Exclusive Flood Control and Annual Flood Control Zone (in feet msl)	Elevation of Multiple Use Zone (in feet msl)
Fort Peck	2246.0	2234.7
Garrison	1850.0	1830.0
Oahe	1617.0	1610.0
Big Bend	None	None
Fort Randall	1365.0	1350.0
Gavins Point	1208.0	1204.5

A-06.9. The selection of these levels was based on the total System storage required for the flood control purpose together with runoff characteristics of the incremental reaches, as defined by the individual System projects. The relationship between the current storage space in the zones defined by these elevations at the major reservoirs and the maximum monthly reach inflow of record is illustrated in Table A-13.

A-06.10. The relatively greater amount of flood control storage space provided in Fort Randall was in recognition of this project's downstream location where re-regulation of upstream projects' flood control releases is required plus Fort Randall's requirement to serve as a temporary storage buffer for significant downstream flood control regulation below the System. The Gavins Point elevations are based on the design studies presented in the Gavins Point Definite Project Report.

Table A-13
Comparison of Current Storage Flood Control Storage Space to the Maximum Monthly Reach Inflow of Record for Each System Project

Project	Max Monthly Reach Inflow	Total FC Storage	Exclusive FC Storage	Ratio of FC Storage to Monthly Reach Inflow Total	Exclusive
	1,000 Acre-Feet				
Fort Peck	4,140	3,692	975	0.89	0.23
Garrison	5,086	5,711	1,489	1.12	0.29
Oahe	3,953	4,303	1,102	1.09	0.28
Fort Randall	1,660	2,294	985	1.38	0.59

A-06.11. These elevations were used in regulation studies VII-D, VII-G, VII-J, and IX-A that are presented in Definite Project Reports. They were, subsequently, also used in study PGOR-6, which was completed in 1953. The elevations were held constant for all studies, although there were considerable variations from study to study in the level of irrigation development assumed (from no depletions to as much as one-fourth the annual runoff at Sioux City). Variations in the storage curves and in the estimated growth and ultimate level of depletions were also used.

A-06.12. The first detailed, long-range regulation study of the System that attempted to systematically reflect the progressive growth of irrigation depletions and the loss of storage to sedimentation, were MRD studies PGOR-10A and 10B, published in April 1956. For those studies, 20.7 MAF of combined exclusive and seasonal flood control storage space (near the maximum developed in preliminary studies of flood control requirements) was assumed to be required under the 1949 level of basin water resource development. Also assumed, the flood control requirements would be reduced to 15 MAF (the minimum requirement developed in preliminary studies) by the year 2010.

A-06.13. Long-range System regulation studies that were conducted in 1958 in connection with cost allocation studies were based on the streamflow depletions that had developed prior to 1949. These studies considered the effects of these depletions on historical runoff into the System. They also assumed a System flood control storage capacity of about 17 MAF for the early years of System regulation, with this value reduced to about 15 MAF by the year 2010 to reflect continued water resource development in the basin.

A-06.14. All of these early, long-term studies reflected the very substantial multiple benefits derived from the System. They also reflected the basic regulation objectives necessary to obtain these benefits through a relatively large range of possible storage allocation alternatives to the flood control function. They also demonstrated the continued performance of the System over the years when depletion in water supplies due largely to irrigation development would occur; sedimentation in the reservoirs could be expected; and a large number of tributary reservoirs, both upstream and downstream from the System, would be constructed.

Appendix B – Recreation

B-01. The six reservoirs of the System and the Missouri River reaches between and downstream of these reservoirs provide recreation opportunities. Recreational activity is a source of income for businesses catering to boating, hunting, fishing, camping, and other recreational pursuits. Service-related establishments located near the river also benefit from those recreating on the System reservoirs. A variety of recreational opportunities are available within the System and the lower Missouri River. Water-based recreation includes boating, boating-related activities, and swimming. Sport fishing is a primary component of recreation along the entire river. The wetlands along the river corridor provide waterfowl habitat, and waterfowl hunting is popular. Hunting for small and large game such as pheasant, grouse, rabbit, and deer occurs on land along the System reservoirs and the river reaches. The aesthetically pleasing character of the reservoirs and river reaches attracts sightseers. Camping facilities vary from fully developed to primitive. Over 80,000 acres of recreational lands are located along nearly 6,000 miles of System reservoir shoreline. Of these 80,000 acres of recreational lands, 6,457 acres are designated as existing recreational areas located on Tribal Reservation lands along the main stem of the Missouri River with another 925 acres identified as future recreational areas. Recreation, an authorized System project purpose, has grown beyond original expectations. With time, recreational facilities became more developed and opportunities for recreation have increased. The introduction of additional fish species attracted greater numbers of fishermen to the reservoirs. Road improvements made the reservoirs and river reaches more accessible. Recently, the national trend towards outdoor recreation and the number of recreationists willing to travel longer distances have added to the recreational visitation all along the System. There is also a viable recreation industry below the System on the lower Missouri River; approximately 30 percent of the total recreation benefits attributed to the Missouri River occur below the System.

B-02. **System Recreation Visitation.** According to visitation data maintained through 1999 by the Corps in the Natural Resource Management System database, a total of 6,731,800 visits (person-trips) are made per year to the six System projects. The project with the greatest number of annual visits is Gavins Point (1,603,900 visits), followed by Oahe (1,544,300 visits), Garrison (1,218,400 visits), Big Bend (1,206,200 visits), Fort Randall (840,900 visits), and Fort Peck (318,100 visits). Of the annual visits made to the six projects, 2,482,430 (37 percent) are made by sightseers, 1,930,157 (29 percent) by fishermen, 1,600,658 (24 percent) by boaters, 640,595 (10 percent) by picnickers, 576,623 (9 percent) by swimmers, 167,677 (2 percent) by campers, 127,724 (2 percent) by water skiers, 166,768 (2 percent) by hunters, and 1,501,594 (22 percent) by visitors who participate in other activities. Plate IV-1 shows the annual visitation graphically for the System and the six System projects. This plate shows that the trend is upward except during extended drought, when the trend levels off or is slightly reversed depending on the year. Other factors also affect the visitation numbers such as the overall United States economy.

B-03. **Recreation Economic Impact.** In addition to visitation data, economic data reveal the extent of recreation on the System reservoirs. The economic impact of recreation at each reservoir has been estimated from a National visitor-spending survey that was conducted in 1999 and 2000 and is presented on the Corps' Value to the Nation website (http://www.corpsresults.us). Capture rates and economic multipliers were estimated using the Impact Analysis for Planning (IMPLAN) system. IMPLAN is a microcomputer-based input-output (I-O) modeling system that is currently maintained by the Minnesota IMPLAN Group, Inc. Spending averages were computed and multiplied by visitation statistics to estimate total annual visitor spending. According to the economic data, a total of $108.26 million in visitor spending is generated annually from the purchase of goods (excluding durable goods like boats and campers) within 30 miles of the six projects, with 56 to 66 percent of the spending being captured by the local economy as direct sales effects. With multiplier effects, visitor-trip spending supports an estimated 2,957 jobs in the local communities surrounding the lakes and results in $109.67 million in total sales and $56.95 million in total income annually.

B-04. **Recreation Purpose**. The recreation purpose is more fully discussed in the Missouri River Master Water Control Manual Final Environmental Impact Statement (FEIS), Volume 1, Main Report, Section 3.12 - Recreation and in this Master Manual in Paragraphs 4-06.7 and 7-08.

B-05. **System Regulation Problems Associated with Recreation.** There is a direct conflict between providing adequate flows to support several other Congressionally authorized purposes and recreation in the large, upper three System reservoirs. During high and normal runoff periods when the three large reservoirs are at normal or above-normal reservoir levels, there is enough water so this conflict is minimized. During prolonged drought periods when water is released for downstream flow support for water supply, navigation, powerplant cooling, downstream river recreation, and water quality, there is a conflict with reservoir recreation at the Fort Peck, Garrison and Oahe projects. This conflict applies at the upper three large reservoirs because they are the only System projects that have Carryover and Multiple Use Zone storage drawn from during drought, or below-normal water supply periods. This storage zone was sized, as discussed in Chapter VII, to serve the authorized project purposes during successive years of drought.

B-05.1. Usually, the reduced runoff period must be greater than 2 years and System storage must be lowered below 52 MAF before a drought begins negatively affecting reservoir recreation significantly. Because the recreation industry has performed through two significant droughts since the System filled in 1967, the recreation facilities at some locations on the three larger System reservoirs have adapted to the lower reservoir levels. There are locations, however, on the three larger reservoirs that have no access during significant drought and cannot adapt other than provide alternative recreation. The three larger System reservoirs were expected to have greatly reduced reservoir levels during extended drought. That is why the upper three reservoirs' Carryover Multiple Use Zone storage is so large compared to other reservoir systems that do not provide water supplementation during significant drought. The Federal Government has provided funds for extending or constructing boat ramps to provide additional or improved access when the upper three System reservoirs have been at lower levels during the two drought periods previously discussed. While this has improved the situation somewhat, reduced recreation benefits at the three larger System reservoirs during drought will continue to be an issue until the recreation facilities are adjusted to function at the lower reservoir levels or alternative recreation opportunities are provided during drought periods.

Appendix C – Water Quality

C-01. **Missouri River Basin Water Quality.** Water quality characteristics that are of greatest concern in the basin are chemical constituents, which affect human health and plant and animal life; temperature, which affect fisheries and the aquatic environment; biological organisms, which affect human health; and taste, odor, and floating materials, which affect the water's potability and the aesthetic quality of the environment. From a historical perspective, water quality degradation has occurred in the Missouri River basin. Although the Missouri River has historically contained high sediment loading and naturally occurring high concentrations of metals such as arsenic and selenium, the water quality characteristics of the Missouri River have changed within the past several decades. These water quality changes are a result of past and current changes in land use practices, increased urbanization, atmospheric deposition of pollutants, and dam construction and regulation within the Missouri River basin. Water quality impacts arising from the construction and regulation of the System can be broadly classified as direct impacts and indirect impacts.

C-01.1. **Direct Water Quality Impacts of System Regulation.** The majority of the water quality degradation that is a direct result of System regulation occurs in the upper portion of the Missouri River basin. These direct water quality impacts include temperature changes in the reaches downstream from several of the dams, low concentrations of suspended solids in the releases, and temperature and dissolved oxygen problems when the upper three reservoirs are drawn down during droughts. These impacts are more physical in nature, involving the management of streamflow and water storage in the System. Water temperature is recognized as an important water quality condition affecting the fishery population in the Missouri River reaches downstream of the dams. Because releases from the System dams contain low concentrations of suspended solids, some native riverine fish species may be adversely affected. The drawdown of the three larger reservoirs during extended droughts diminishes the cold water habitat (the temperature increases are a direct impact of System regulation and less dissolved oxygen being available in the reservoirs is an indirect impact, as discussed below). In turn, cold water fish species in the reservoirs may be adversely affected.

C-01.2. **Indirect Water Quality Impacts of System Regulation.** Most water quality impairments in the Missouri River basin are indirect impacts as they result from a combination of pollutant sources and hydrologic conditions throughout the watersheds. The Missouri River reservoirs and the tributaries receive pollutant loading from point and non-point sources within the watersheds. The Corps is not the source of the pollutants that enter the Missouri River; however, it is responsible for managing the hydrologic regimes that store or transport pollutants downstream. Water quality impairments and problems may, therefore, arise when the Corps is regulating the System to meet the Congressionally authorized System project purposes. Brief descriptions of these indirect water quality issues and impacts are discussed below.

C-01.2.1. During extended droughts, low reservoir levels in the summer generally lead to lower dissolved oxygen levels in the deeper, cooler portions of the three larger System reservoirs. This volume reduction may cause an increase in the overall temperature of the water in the reservoir and may reduce the total amount of oxygen available to meet demands of sediment and decomposing organic material, such as decaying algae.

C-01.2.2. Dissolved oxygen concentrations, especially in hypolimnetic waters, can be lowered through the decomposition of accumulated organic matter and the oxygen demand of sediments and reduced substances. The absence of dissolved oxygen (anoxic conditions) during summer conditions may result in an influx of metals, such as iron and manganese, from the sediments into the water column. Anoxic conditions, through the oxidation-reduction process, can also liberate nutrients such as phosphorus from the sediments. This can lead to nutrient enrichment and possible nuisance growth of algae.

C-01.2.3. Elevated heavy metal concentrations have been detected both in the water column and within the sediments of the System. The major metals of concern in the System are arsenic and mercury. Arsenic and mercury concentrations greater than State water quality criteria have been detected in several of the System reservoirs. Natural background concentrations of arsenic, selenium, and mercury in the System reservoirs are associated with the local geology, specifically the presence of Upper Cretaceous age Pierre Shale. Arsenic is a water quality parameter that commonly exceeds water quality standards criteria in the System reservoirs. Elevated arsenic concentrations are a localized occurrence associated with large storm events that cause high sediment loading or wind action that results in re-suspension of the reservoir sediments. Arsenic is a naturally occurring metal within the watershed and readily adsorbs onto fine soil particles as they are transported downstream and deposited in the reservoirs. The majority of arsenic entering the System is adsorbed onto sediment particles. The sources of mercury are naturally occurring soils, point-source discharges, and sediments generated from historical mining practices that have been transported downstream into the System reservoirs. Through biological uptake and transformation, mercury can become toxic to fish and humans in the form of methyl mercury. Other metals that have been detected in elevated concentrations in the System reservoirs are copper, lead, iron, and manganese.

C-01.2.4. Agricultural practices, both past and present, include the application of pesticides throughout much of the Missouri River basin. Pesticides detected include chlordane, atrazine, alachlor, diazinon, dacthal, benzene hexachloride, metolachlor, dieldrin, DDT, simazine, metribuzin, and propachlor. Because of the widespread occurrence of pesticides, bioaccumulation of some pesticides in the tissue of aquatic organisms is a potential threat to all consumers of these organisms.

C-01.2.5. Tributary waters exhibit significant nutrient loadings because of effluent discharges, urban storm water and agricultural runoff, and other non-point sources of pollution. High nutrient levels in the Missouri River and its tributaries can deliver nutrients to the System reservoirs and lead to undesirable algal blooms.

C-01.3. **System Reservoir Water Quality.** Specific water quality problems and issues detected in the System reservoirs are presented in Table C-1. This table summarizes the water quality conditions of the reservoirs (inflow, reservoir, and outflow locations). This table also provides information on the length, surface area, volume, and daily inflow rates. Specific reservoir water quality issues are discussed below.

C-01.3.1. **Fort Peck Lake.** The State of Montana has placed Fort Peck Lake on the 303(d) List of Impaired Waterbodies owing to lead, mercury, other metals, and noxious aquatic plants. The identified sources of these pollutants and conditions are agriculture, abandoned mining, and atmospheric deposition. Inflows and waters within Fort Peck Lake have a low pH and elevated levels of arsenic, phosphorus, mercury, manganese, beryllium, and iron. The Montana Department of Public Health and Human Services has published a "Meal Advisory" for the consumption of certain species and size of fish caught in Fort Peck Lake, due to mercury in fish tissue. Dissolved oxygen levels in the deeper waters of the reservoir and in dam releases are, at times, below saturation levels, indicating the possible presence of oxygen-demanding materials in sediments or excessive algal blooms. The die-off of algal blooms and subsequent settling of organic matter contribute to the oxygen demand of the deeper isolated waters of the reservoir. Toxins associated with algal blooms have been detected in isolated areas of the reservoir. As water levels drop during extended droughts, algal blooms have a greater impact on dissolved oxygen conditions.

C-01.3.2. **Lake Sakakawea.** Lake Sakakawea is on the State of North Dakota's 303(d) List of Impaired Waterbodies. The listed impaired uses are fish and other aquatic biota and fish consumption. The identified pollutants and stressors are low dissolved oxygen water temperature and methal mercury. Algal blooms occur at times in the reservoir during low reservoir conditions. A toxic algal bloom occurred in the reservoir in 1990 when the reservoir was down to elevation 1,815 feet msl during a drought. Organic materials, such as decaying algae and imported organic matter, contribute to the in-reservoir oxygen demand and result in reduced dissolved oxygen levels in the deeper, cooler portion of the reservoir. Dissolved oxygen concentrations may fall below 5 mg/l in the deeper, cooler portion of the reservoir, and cold water habitats may be reduced during drought conditions. Elevated concentrations of arsenic, mercury, copper, iron, lead, and pesticides have been detected in Lake Sakakawea (personal communication, F.J. Schwindt, Chief, Environment Health Section, State of North Dakota, 1995). Observed arsenic and mercury levels are below the Environmental Protection Agency's (EPA's) recommended drinking water standards. Atrazine was also detected in Lake Sakakawea; however, State criteria have not yet been developed for this pesticide. The North Dakota Department of Health and Consolidated Laboratories (NDDHCL) has issued an advisory on consumption of fish caught in some streams and reservoirs in North Dakota.

C-01.3.3. **Lake Oahe.** Lake Oahe is not on the State of South Dakota's 303(d) List of Impaired Waterbodies. Low dissolved oxygen levels may occur, especially at low reservoir levels, in deeper portions of the reservoir in the summer or in shallow bays during the winter. Winterkills of fish sometimes occur in these bays. Elevated concentrations of arsenic, manganese, iron, and beryllium have been monitored in Lake Oahe and its inflows. Elevated levels of mercury have also been found at times and in certain locations. The elevated concentration of mercury is primarily isolated to the Cheyenne River and Cheyenne Arm of Lake Oahe, which runs along the southern boundary of the Cheyenne River Reservation. While a past point source of the mercury is now controlled, sediments in the river and lake remain contaminated and continue to be deposited in Lake Oahe. The water quality parameters of concern within the reservoir are arsenic, dissolved oxygen, pH, iron, lead, manganese, and copper. The major source of pollutants is agricultural runoff.

C-01.3.4. **Lake Sharpe**. Lake Sharpe was removed from the State of South Dakota's 303(d) List of Impaired Waterbodies in 2003. It was previously listed due to accumulated sediment in close proximity to the Bad River Section 319 Nonpoint Source Management Project. Lake Sharpe may experience dissolved oxygen depletion in its deeper, cooler waters during summer conditions. Water quality parameters of concern are dissolved oxygen, sulfate, and arsenic. Lake Sharpe receives agricultural runoff containing pesticides and nutrients. Elevated levels of PCBs and pesticides have been monitored. Lake Sharpe receives very little sediment inflow from the Missouri River due to the close proximity of Oahe Dam. An extensive delta has formed due to sediment deposition from the Bad River.

C-01.3.5. **Lake Frances Case.** Lake Francis Case is not on the 303(d) Listing of Impaired Waterbodies in South Dakota. Dissolved oxygen, arsenic, phosphorus, and mercury levels are, at times, elevated. The Corps' Omaha District Water Quality Annual Report in 2000 mentioned that the observed concentrations may restrict the propagation of sensitive species. Although the Environmental Protection Agency's (EPA's) recommended drinking water standards criteria for arsenic and mercury were not exceeded, the Corps recommended that local municipalities monitor raw water intakes. Elevated concentrations of arsenic, pesticides, lead, mercury, cadmium, and zinc have also been measured in the reservoir.

C-01.3.6. **Lewis and Clark Lake**. Lewis and Clark Lake is not on the 303(d) Listing of Impaired Waters in Nebraska or South Dakota. Dissolved oxygen levels, however, are at times depressed in the reservoir during summer stratification. Arsenic, iron, mercury, manganese, and lead concentrations are at times elevated. The Corps' Omaha District Water Quality Annual Report in 2000 mentioned that these elevated concentrations may restrict the propagation of sensitive species. Although the EPA's recommended drinking water standards criteria for arsenic and mercury were not exceeded, the Corps recommended that local municipalities monitor raw water intakes. Pesticides and mercury have been detected in fish tissue samples taken from the reservoir. The Nebraska Department of Environmental Control collected fish tissue samples from Lewis and Clark Lake in 1988. The tissue samples contained cadmium, mercury, and DDT.

C-02. **Water Quality Considerations.** With the exception of some tributary streams and isolated reaches of the Missouri River below cities and industries, water quality problems in the Missouri River basin have been relatively minor. Storage space has been provided in a few tributary reservoirs to serve this purpose. Recent emphasis has been on wastewater treatment facilities rather than the dilution of poor quality water by use of storage facilities. Consequently, Missouri River flows ranging from 3,000 cfs at Sioux City to 9,000 cfs at Kansas City are considered adequate for water quality purposes.

C-02.1. **System Water Quality History.** The above paragraphs describe, in some detail, the existing status of water quality in the System and the direct and indirect water quality impacts of System regulation. Table C-1 provides potential problem areas and State standard concerns for each System project. Also, the FEIS, Chapter 3, Section 3.5 and the FEIS, Appendix B describes, in considerably greater detail, water quality concerns from a historic and current reservoir regulation perspective. That information will not be repeated here but is available from the RCC website.

Table C-1
System Reservoir Water Quality and Physical Description Summary

Project	Potential Problem Areas	State Standard Concerns	Length (miles)	Surface Area (acres)	Gross Volume (acre-feet)	Mean Daily Inflow (kcfs)
Fort Peck Lake, MT Missouri River Mainstem	Coal and oil, development, algal blooms	Inflows: None identified Lake: Arsenic, mercury, dissolved oxygen Releases: Arsenic	134	240,000	18,688,000	10.8
Lake Sakakawea, ND Missouri River Mainstem	Oil dripping, strip mining, algal blooms, metribuzin	Inflows: None identified Lake: Arsenic, mercury, dissolved oxygen Releases: None identified	178	364,000	23,821,000	24.0
Lake Oahe, SD Missouri River Mainstem	Ag runoff, mercury, bioaccumulation, metribuzin	Inflows: None identified Lake: Mercury, total phosphorus, iron, sulfate Releases: Arsenic, mercury, sulfate, total phosphorus	231	360,000	23,137,000	26.7
Lake Sharpe, SD Missouri River Mainstem	Ag runoff, atrazine	Inflows: None identified Lake: Mercury, sulfate, dissolved oxygen Releases: Sulfate	80	60,000	1,859,000	25.8
Lake Francis Case, SD Missouri River Mainstem	Intrusion of the white river delta, metribuzin, atrazine	Inflows: None identified Lake: Mercury, sulfate, dissolved oxygen, total phosphorus, arsenic Releases: Sulfate, mercury	107	95,000	5,418,000	26.8
Lewis And Clark Lake, SD Missouri River Mainstem	Emergent aquatic vegetation, atrazine, cyanazine	Inflows: Sulfate, mercury Lake: Mercury, sulfate, dissolved oxygen, arsenic Releases: Sulfate, total phosphorus, arsenic	25	28,000	470,000	29.3

Notes: Length, surface area, and gross volume are at full pool levels. Mean daily inflow is for the period 1967 to 2000.
Source: NWD - Omaha District Water Quality Annual Report

C-02.1.1. A program began in 1967 to monitor the quality of releases from all System projects and to sample the reservoirs and inflow from major tributaries. The Corps' Water Quality Management Program for the System currently consists of an analysis of the reservoirs and their releases. The U.S. Geological Survey (USGS) monitors inflowing tributaries. Remote monitoring of releases for dissolved oxygen, pH, conductivity, and temperature occurs at all of the System projects. Monitoring is conducted to detect water quality problems and determine compliance with Federal water quality criteria and State and local water quality standards. An annual water quality report prepared by the Corps' Omaha District summarizes the ongoing and planned activities of the program and water quality conditions at each project. This report should be consulted for a detailed current status of the water quality conditions at each System project.

C-02.1.2. Potential concerns that may result from the System projects or their regulation include (1) the potential for gas super saturation if spillway releases are made from Fort Peck and Gavins Point Dams; (2) hypolimnetic oxygen depletion in Fort Peck Lake, Lake Sakakawea, and Lake Oahe; (3) occasional fish kills below Oahe, Fort Randall, and Gavins Point Dams; and (4) increased rates of eutrophication in the reservoirs due to accumulation and recycling of nutrients in the reservoirs.

C-02.1.3. The System projects have a significant moderating influence on Missouri River water temperatures and sediment concentrations. Most of the inflowing sediment load is retained within the impoundments. Winter releases from the dams cause a slight warming of the downstream waters ranging from 1 to 3°C. In the late spring, summer, and early fall, river temperatures downstream of the upper three projects are depressed on the order of 5 to 10°C due to the release of colder water from their dams.

Appendix D – Fish and Wildlife

D-01. **General**. Development of the System has transformed a major portion of the Missouri River valley extending from eastern Montana through the Dakotas from an area typical of alluvial streams into a chain of long, relatively deep reservoirs. This development, in an area where such a quantity of surface water did not exist naturally and that is characterized as having a relatively dry climate, has had a great effect upon the environment of the area. The purchase and subsequent management of lands associated with the individual System projects has changed use patterns of lands adjacent to the System projects from the use experienced prior to projects. Regulation of the reservoirs also has affected the regime of the Missouri River through those reaches below the System and in those reaches between the System reservoirs where the river is still more or less in its natural state. The full impact of each of the reservoirs and its regulation on the environment is constantly changing as they adapt to new conditions. The environmental emphasis has changed since the System was authorized. Current efforts are focused on increased stewardship of the Missouri River and surrounding affected lands by maintaining them in as natural a condition as possible through enhancing and supporting native plants and species. The two basic goals of the Corps stewardship are to manage lands and waters to ensure their availability for future generations and to help maintain healthy ecosystems and biodiversity. Balancing the needs of the people with those of nature is the basic challenge. Through observations and discussion with interested individuals and agencies, many suggestions for environmental enhancement of the System have been received and are being implemented by the Corps. The adaptive management process discussed in Chapter VII will provide additional focus on this effort, and, through implementation of the actions developed and tested through this process, Missouri River ecosystem restoration will occur.

D-01.1. Another major point of emphasis in environmental considerations has been the effect of the various System regulation practices on fish and wildlife, including threatened and endangered species. Improvement of fish spawning activities by appropriate management for habitat development and subsequent spawning is an important consideration in System regulation. Suggestions have been made and adopted to the degree practical for improving migratory waterfowl habitat and hunter access along the river below the projects. Other suggestions, such as reduction of flows during the migration period so that more sandbars could be available, cannot always be implemented without serious effects on other authorized project purposes. As further suggestions are received, they will be evaluated through the adaptive management process. Another area of environmental concern is the management of project lands. Currently, the major emphasis on the development of these lands is for water-oriented recreation; however, large areas of project lands are now being managed almost exclusively for wildlife.

D-02. **Fish and Wildlife.** Fish and wildlife enhancement has been discussed in other portions of this Master Manual. Chapter IV, Paragraph 4-06.6 presents information on the activities of two existing Federal National Fish Hatcheries and the Fort Peck National Fish Hatchery that is currently being constructed. At all times of the year, but particularly during the fish spawning period and the endangered species nesting season, the RCC recognizes and integrates fish and wildlife purpose considerations into System regulation decisions. The Corps coordinates closely with the Service and the State organizations to assure that the consideration of effects on fish and wildlife is provided. The following paragraphs provide a detailed discussion of the existing Missouri River basin environment and historical System regulation related to this authorized purpose. The goal of this updated water control plan is to continue to provide environmental stewardship in managing the natural resources in the Missouri River basin while recovering the Missouri River ecosystem.

D-02.1. **Missouri River Wildlife Habitat.** The Missouri River creates and maintains important forest and wetland habitat for a wide diversity of wildlife, including at least 60 species of mammals, 301 species of birds, and 52 species of reptiles and amphibians. Of these, five bird and two bat species occurring in the river valley are Federally listed as threatened or endangered. Because much of the river's course traverses the arid Great Plains, where less than 5 percent of the land supports trees, the densities and distributions of many of these wildlife species depend on the forests and wetlands associated with the river. The diversity and abundance of wildlife reflects the diverse mix of habitat classes occurring in the Missouri River valley, which includes riverine; reservoirs, lakes and ponds; emergent, scrub-shrub, and forested wetlands; riparian forests; grasslands; and croplands. The combination of open water, wetlands, and riparian vegetation is particularly important for the large number of waterfowl that stop along the Missouri River during spring and fall migration.

D-02.1.1. The river hydrology and morphology influence the composition and distribution of vegetation on the floodplain, causing habitat changes on a daily, seasonal, annual, and long-term basis. Erosion and sediment transport play an important role in the creation and degradation of sandbar habitat, scouring or elimination of vegetated lands, and creation of suitable substrate for plant germination and the initiation of early-successional plant communities. Seasonal flow patterns dictate the frequency and duration of wetland flooding and maintain oxbow lakes that are important for breeding and foraging wildlife. Reservoir storage levels determine the water depths in wetlands located along the six System reservoirs and the extent of exposed shoreline.

D-02.1.2. The Missouri River, extending from the headwaters of Fort Peck reservoir to Gavins Point Dam, contains a relatively diverse mix of wetlands, riparian habitats, riverine open water, and open water associated with the six System reservoirs. The highly variable water levels of the System reservoirs can produce extensive zones of wetland or weedy herbaceous wildlife habitat that establishes on exposed shoreline sediments. The large wetland/riparian complexes that have developed at the upstream end of each reservoir also provide productive habitat and are actively managed for wildlife. Productive habitat in the lower Missouri River downstream of Ponca is largely restricted to the old oxbows and chutes that were partially or entirely cut off from the river by dikes and revetments. For this reason, many of the larger river bends in Nebraska, Iowa, Missouri, and Kansas are managed as State wildlife management areas.

D-02.2. **Fishery Management.** Over 156 fish species have been documented in the Missouri River. These species include a wide variety of native species and numerous species that have been introduced into the System reservoirs and riverine stretches of the Missouri River. The habitat classes available and, correspondingly, the species composition of the Missouri River differ considerably between the riverine and reservoir segments. The reservoirs formed by the six dams on the Missouri River changed the character of the river and thus the fish habitat. Even the Missouri River reaches below the dams have changed, particularly in terms of water temperature, clarity, chemical composition, and bottom configuration and substrate. The additional diversity of habitat has led to a greater diversity in the fish community. The river and reservoir fisheries and habitat will be discussed in the following sub-paragraphs.

D-02.2.1. **Riverine Fish.** The most important sportfish in the open river reaches are walleye, sauger, white bass, yellow perch, channel catfish, paddlefish, shovelnose sturgeon, and northern pike. Trout and salmon and smallmouth bass are also targeted in many of the tailrace fisheries below the dams. Until recently, channel catfish, bigmouth buffalo, smallmouth buffalo, flathead catfish, goldeye, and suckers were fished commercially in some areas.

D-02.2.2. **Native Fish.** The native river fishes are the fishery that existed in the Missouri River prior to the construction of the System. Native river fishes including the catfish, sturgeon, sauger, suckers, and paddlefish, have declined as a result of; migration blockage, loss of habitat, change in habitat, and competition from new species that have taken advantage of these changes. The pallid sturgeon has been listed as an endangered species. Paddlefish populations have declined sharply and paddlefish are being considered for threatened or endangered status. Currently, a moratorium on the commercial harvest of catfish is in effect in the Lower Missouri River. Dams, channelization, river channel degradation, farmland reclamation, and reduced peak flood flows have contributed to the loss of important fish habitat in the Missouri River. Other common native species in the river include carp, river carpsucker, shorthead redhorse, freshwater drum, and goldeye. Shortnose gar, gizzard shad, flathead chub, blue sucker and several shiners are also common in some parts of the Missouri River.

D-02.2.2.1. **Native Fish Habitat.** Natural seasonal flow patterns to which many of the native fishes originally adapted have changed on the Missouri River. High spring flows that provided additional shallow water habitat have been nearly eliminated on some sections of the Missouri River and reduced on others. Most riverine fish depend on the remaining low-velocity, shallow-water habitat at some point in their life history. Several species spawn in such habitat, and the juveniles of most species rear in low-velocity regions until they are large enough to maintain themselves and avoid predation in the higher velocity flows of the Missouri River's main channel. Many species spend their entire lifetime in the low-velocity areas of the river. Backwaters, side channels, and other low-velocity habitat are currently limited in some of the remaining river reaches.

D-02.2.2.2. Some new aquatic habitat was created during the high flows and flood events on the Missouri River in 1993 and 1995. Numerous scour lakes were also created on the lower Missouri River during 1993, and several remain connected to the river, providing habitat for fish larvae, juvenile, and adult small fishes. In addition to restoring aquatic habitat, the floods of 1993 and 1995 temporarily reconnected previously isolated wetlands, thus augmenting the value of those wetlands to include Missouri River fishery benefits. Floodplain connections of wetlands benefit fish when water temperatures are appropriate for spawning and larval development. The 1993 flood created an estimated 1,170 acres of connected scour lakes and wetlands and 2,052 acres of unconnected scour lakes and wetlands. In addition, the Corps' Kansas City District created more than 2,000 dike notches to provide additional shallow water habitat.

D-02.2.3. **Cold Water Riverine Fish Habitat.** Tailwaters differ from the natural river habitat in temperature, turbidity, substrate, current and flow patterns, food supply, and the ensuing difference in species assemblages. Because of the low sediment load of the Missouri River below the dams, tailwaters frequently exhibit bed degradation, deep pools, coarse bed materials, and high biotic diversity. The cool or cold water releases from the dams support cool water and cold water fisheries. Trout, salmon, walleye, sauger, northern pike, smallmouth bass, and many other species use the cooler waters below the dams. Most of these populations are self-sustaining, although some, especially trout and salmon, are supported or enhanced by stocking. The quantity of cold water habitat available downstream of the dams is a function of the quantity of water released from the dams during the summer months and the temperature of that water. When reservoir levels are low, water releases from the dams may be several degrees warmer and provide less cold water habitat downstream.

D-02.2.4. **Endangered Riverine Fish.** A native Missouri River fish of primary concern is the endangered pallid sturgeon. The historic range of pallid sturgeon, encompassed the middle and Lower Mississippi River, the Missouri River, and the lower reaches of the Platte, Kansas, and Yellowstone Rivers. Because the pallid was not recognized as a distinct species until 1905, little is known about its abundance and distribution prior to this date. They have always been uncommon. Hybrids of the shovelnose and pallid sturgeon have been collected and may be common in the lower Missouri River. Some surveys suggest a probable decline in the abundance of pallid sturgeon from former levels. According to the Pallid Sturgeon Recovery Plan, modification of the natural hydrograph, habitat loss, migration blockage, pollution, hybridization, and over harvesting are possibly all responsible for this decline.

D-02.2.4.1. The paddlefish, another large native species, is a candidate species for threatened or endangered status under the ESA. Blockage of migrations, over harvest, and loss of deep pool habitat are among the key factors believed to be affecting their populations. Recent studies indicate a positive relationship between larval paddlefish abundance below Fort Randall Dam and the volume of discharge from Fort Randall Dam. Other native fish species are also declining. Several other species have been classified as species of special concern by the various states located along the Missouri River. Little is known about the biology or specific habitat requirements of many of these species, although several recent studies are shedding some light on habitat use. This water control plan recognizes the importance of improving the native river fishery. The Corps will work with others through the adaptive management process discussed in Chapter VII to implement those steps necessary to assure the recovery of the native river fish.

D-02.2.5. **System Reservoir Fisheries.** The six System reservoirs contain a diverse community of cold water, cool water, and warm water fishes. The three larger reservoirs have been stocked with cold water game and forage fish species to take advantage of the cold water habitat that is retained through the summer and fall in the lower depths of the lakes. These species include chinook salmon, brown trout, rainbow trout, lake trout (Fort Peck Lake only), cisco (forage in Fort Peck Lake), and rainbow smelt. Species in the three smaller reservoirs and in the warmer waters of the three larger reservoirs include native and non-native species that have adapted to lacustrine conditions. Some of the most common of these species are walleye, sauger, goldeye, carp, channel catfish, river carpsucker, crappie, gizzard shad, and emerald shiner. Smallmouth bass have also been stocked in several of the System reservoirs. White bass and northern pike are common in several reservoirs. Many of the species present in the reservoirs support sports fisheries.

D-02.2.5.1. **Reservoir Fishery Habitat.** Natural reproduction of the fish populations of the six System reservoirs is limited by the availability of spawning and young-of-year rearing habitat. The cold water species generally lack spawning habitat and, thus, are primarily supported by hatcheries. An exception is the lake trout in Fort Peck Lake, which spawn naturally in the rock riprap along the dam face. Most of the warm water and cool water species spawn in shallow habitat of the reservoir shorelines, in the river above the lakes, or in tributary streams. Walleye and, to a lesser degree, sauger require clean rock in moderately shallow water for suitable spawning habitat. Northern pike and several other warm water species spawn in submerged vegetation. The effect that the availability of spawning habitat has on the production of fish was evident when the reservoirs were first filled. Rising waters inundated vast areas of terrestrial vegetation. The populations of northern pike and other species requiring vegetated spawning and rearing habitat increased dramatically. These species also prospered from an abundance of small forage fish. Upon the eventual decay of submerged vegetation, the reservoirs declined in productivity and many species began to decline. Other factors that affected the production of fish include the gradual decline of shallow-water habitat as embayments fill with sediment and shorelines are smoothed.

D-02.2.5.1.1. Coincident with the decline in these populations, walleye abundance increased as a result of stocking and improved spawning habitat. During the 1987 to 1993 drought, the upper three reservoirs were drawn down about 20 to 25 feet below the base of the annual flood control level, draining much of the shallow habitat normally found in bays, exposing available clean rock, and limiting the availability of submerged vegetation to support spawning and rearing. Concern arose regarding the System’s ability to maintain the productivity of the important game and forage fishes. Stocking was increased to maintain populations of game fish. The high productivity in the upper reservoirs was a result of the System filling following the drought. During the extended drawdown period, vegetation developed along the normally inundated shorelines that now provide new spawning and rearing habitat.

D-02.2.5.2. **Reservoir Cold Water Habitat.** Cold water habitat available to support the popular trout and salmon fisheries is decreased during periods of drought. The amount of well-oxygenated cold water retained through the summer and fall is related to the water level in the upper three reservoirs. Habitat in the lower three System reservoirs has been affected very little by drought because these reservoirs are regulated at the same levels regardless of wet, normal, or drought conditions. Little cold water habitat is retained through the summer and fall in these reservoirs due to their smaller size and the high quantity of warm water flowing through the reservoirs. Flow rates through the lower three reservoirs varies considerably from year to year based on runoff conditions. High flows may reduce primary and secondary productivity, spawning success, and could flush fish from the reservoirs. Higher flows, however, are required for the evacuation of accumulated flood storage during high runoff years.

D-03. **Fish and Wildlife Purpose Accomplishments.** There have been significant benefits provided to fish and wildlife in the reservoirs and river reaches between the projects from the construction of the System. Since the System filled in 1967, the Mainstem reservoirs have been regulated to enhance the fish population associated with the reservoirs. Currently, 156 fish species are known to occur in the Missouri River and the System. These include native species and many others that have been introduced over the years. A diverse community of cold water, cool water, and warm water fish inhabit the six reservoirs of the System. The upper three larger reservoirs have been stocked with cold water game and forage species to take advantage of the cold water retained through the summer and fall in the deeper waters of the reservoirs when the storage in these reservoir has not been depleted by drought. The past accomplishments in fish and wildlife enhancements could be expressed in many ways. The greater-than-expected improvement in upstream recreation is directly related to the enhancement of the fishing and wildlife activities associated with the System reservoirs. Also, most State records are from the System reservoirs. Large areas are preserved for the diverse basin wildlife on System project lands. Early attempts to manage reservoir levels to inundate reservoir vegetation for fish spawning and control of releases to encourage downstream spawning below reservoirs have been documented. The success of the fish in the System and on the Missouri River below the System depends on habitat conditions. Water levels, inflow, and outflow are important factors in the reservoirs. Native fish in the river reaches are naturally adapted to warm, muddy high spring and early summer flows, and also to the lower late summer and fall flow characteristics of the historic Missouri River. The cold, clearer tailwaters of the upper three large System reservoirs are more conducive to trout and salmon, but not the paddlefish, pallid sturgeon, and other native river fish. The RCC will continue to work with State and Federal interests to optimize the benefit to fish and wildlife through regulation of the System. The specific minimum release criteria are discussed in Chapter VII, Paragraphs 7-10 of this Master Manual.

D-04. **Historic System Regulation for Endangered and Threatened Species - Terns and Plovers.** While the Missouri River provides habitat for a wide variety of wildlife species, the endangered least tern and threatened piping plover are of particular importance. They depend on unvegetated sandbars and islands in the river for nesting and are directly affected by water level changes. These birds typically nest in colonies on river sandbars, sandy shorelines of reservoirs, or in sandpits along the river. Important nesting reaches are below Fort Peck, Garrison, Fort Randall, and Gavins Point Dams, and on Oahe and Garrison reservoirs. River hydrology and channel characteristics influence the composition and distribution of tern and plover habitat along the river. Seasonal river flow and water level patterns dictate the frequency and duration of habitat flooding and the scouring of sandbar vegetation. Bank erosion and sediment movement in the riverbed also affect the creation and removal of sandbar and island habitat. Declining reservoir levels result in exposed bare shoreline increasing nesting habitat. Specific System regulation criteria used in the past for endangered species nesting is discussed in Chapter VII, Paragraphs 7-10 of this Master Manual.

D-04.1. The RCC has been regulating the System for interior least tern and piping plover nesting since 1986. Real-time stream gages have been installed on the Missouri River in the critical nesting reaches specifically to monitor stream flows during the nesting season. These gages provide a check, as well as a stage history, throughout the season to help relate the effects of regulation and natural events at intervals along the Missouri River. The gaging data must be supplemented with observations of nesting activities and conditions to provide all the information that is needed for regulation decisions. A dynamic flow routing model has been developed to forecast maximum river stages along the river for different combinations of daily discharge and hourly power peaking characteristics. Beginning in 1999, the Omaha District created a computerized Threatened and Endangered Species Data Management System. Report data, which is updated daily, includes nest records, census and productivity data, site descriptions, field journals, and messages. The use of this database is a valuable tool in aiding release decisions benefiting endangered and threatened birds. Table D-1 shows the population distribution and productivity for terns and plovers for 1991 through 2003. Productivity estimates for these birds on the Missouri River in 2003 include only natural nesting. Adult birds in this table are considered breeders even though they may not have had nesting success. The term "fledglings/pair" means the number of young birds produced per breeding pair. This ratio is an estimate, as the fate of every single fledgling is impossible to obtain.

Table D-1
Missouri River Main Stem
Least Tern and Piping Plover Survey Data

Interior Least Tern

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Fort Peck Lake														
Adults	6	10	0	7	9	2	0	0	4	0	0	0	0	2
Fledglings/Pair	-	0.40	‡	0	0.44	0	0	0	0	0	0	0	0	0
Fort Peck to Lake Sakakawea														
Adults	92	66	110	31	58	95	128	162	25	40	13	39	34	38
Fledglings/Pair	0.17+	0.55+	0.25+	0.45+	1.41+	0.99+	0.33	0.53	.152	1.70	0.15	0.97	0.59	0.63
Lake Sakakawea														
Adults	6*	8	29+	17	35	7	27	2	23	9	10	34	21	25
Fledglings/Pair	-	-	0.83+	0.12+	0	0	0.15	0	1.04	0.67	0.20	0.76	0.86	0.56
Garrison to Lake Oahe														
Adults	174	195	198	145	217	284	105	41	141	105	105	125	126	144
Fledglings/Pair	0.44+	0.58	0.48	0.28	0.54	0.91	0.08	0.39	1.52	1.50	1.03	1.26	1.83	1.28
Lake Oahe														
Adults	100	143	124	125	160	84	74	101	110	57	85	94	106	70
Fledglings/Pair	-	-	0.42	0	0.06	0	0.24	0.16	1.29	0.88	1.01	1.34	1.32	1.20
Ft. Randall to Niobrara														
Adults	26	32	13	38	43	10	2	0	64	124	72	71	84	50
Fledglings/Pair	0.31+	0.63	0.46	0	0	0	0	0	0.94	1.03	1.26	0.14	0.71	0.92
Lake Lewis and Clark														
Adults	63	55	29	76	44	16	28	60	120	76	44	58	46	46
Fledglings/Pair	0.35+	0	1.59	0.97	0	0	0	1.57	2.33	0.21	0.38	1.17	1.04	0.39
Gavins Point to Ponca														
Adults	167	193	187	272	211	93	82	115	148	161	149	232	314	366
Fledglings/Pair	0.46+	0.26	0.21	0.83	0.48	0.49	0.27	0.90	2.27	2.41	1.72	1.09	1.32	0.75
Total Adults	634	702	690	711	777	591	446	481	635	572	551	653	731	741
Fledglings/Pair	0.38	0.41	0.42	0.50	0.41	0.67	0.21	0.66	1.73	1.42	1.22	1.04	1.27	0.87

Ten Year Interior Least Tern Fledge Ratio Goal = 0.70 (2000 Biological Opinion)

Piping Plover

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Fort Peck Lake														
Adults	22	25	26	30	4	5	0	0	4	2	0	4	2	17
Fledglings/Pair	3.18	1.20	1.00	0.60	1.50	1.20	0	0	0	2.00	0	1	2	0.35
Fort Peck to Lake Sakakawea														
Adults	17	13	0	4	9	20	24	23	4	5	4	3	2	6
Fledglings/Pair	0	0	‡	0+	0	3.50	1.00	0.87	1.00	0	0	1.33	0	2.67
Lake Sakakawea														
Adults	132	150	108	8	45	24	70	3	119	83	277	424	469	528
Fledglings/Pair	-	-	1.50	8.5+	1.24	0	0.57	0.67	1.24	1.25	1.61	1.25	1.65	1.06
Garrison to Lake Oahe														
Adults	71	124	77	127	119	261	45	6	74	139	99	149	119	149
Fledglings/Pair	1.04+	1.13+	1.06+	0.54+	0.87	0.87	0.09	0	1.84	0.88	1.41	1.53	2.03	1.66
Lake Oahe														
Adults	88	87	143	66+	85	30	21	31	98	46	141	184	203	301
Fledglings/Pair	-	-	0.97+	0.33	0.09	0.93	0.29	1.29	1.06	0.30	1.45	1.41	2.16	1.84
Ft. Randall to Niobrara														
Adults	12	25	8	12	17	0	3	0	33	51	62	38	35	37
Fledglings/Pair	0.67*	0.48	0.75	0	0	0	0	0	1.27	1.02	0.87	0.74	1.03	1.46
Lake Lewis and Clark														
Adults	30	33	6	32	12	4	6	32	84	67	28	34	44	14
Fledglings/Pair	0.67+	0	0	0.06	0.33	0	0	1.25	2.45	0.30	0.5	0.71	1.68	1.57
Gavins Point to Ponca														
Adults	148	166	112	109	62	63	22	22	49	141	186	218	260	286
Fledglings/Pair	0.39+	0.35	0.34	1.06	0.61	0.16	0	0	2.20	1.60	2.17	1.85	2.29	1.9
Total Adults	521	623	480	388	353	407	191	117	465	534	737	1054	1134	1338
Fledglings/Pair	0.76	0.62	0.34	0.76	0.61	0.84	0.39	0.87	1.61	1.01	1.58	1.41	1.31	1.5

Fifteen Year Piping Plover Fledge Ratio Goal = 1.13 (2000 Biological Opinion)

- Data not collected

* Partial Survey Results

‡ No Birds Found

\+ Subsampling of Selected Nesting Areas

The data does not include least terns and piping plovers raised in captivity. The data represents only wild fledged birds.
From 1990 to 2000 the Fifteen Year Piping Plover Fledge Ratio Goal was 1.44 (1990 Biological Opinion).
From 1990 to 2000 the Ten Year Least Tern Fledge Ratio was 0.70 (1990 Biological Opinion).
Data in this table may differ from previous reports. As information becomes available, this table is updated.

Appendix E – Water Supply And Irrigation

E-01. **Introduction.** System regulation has assured a relatively uniform supply of water for downstream municipalities and industrial uses. The Corps provides more than adequate flow in the river to meet the requirements of all who choose to utilize the Missouri River for their water supply. At times, releases from individual System projects have been adjusted to assure continued satisfactory functioning of water intakes on a short-term basis. The Missouri River and its System reservoirs are a source of water for municipal water supply; irrigation; cooling water; and commercial, industrial, and domestic uses. Approximately 1,600 water intakes of widely varying size are located within the System and the lower Missouri River. Access to water is a key concern because low water levels increase the cost of getting water from both the reservoirs and Missouri River. Water supply is a purpose that has grown more than originally envisioned. The regulation of the System in such a predictable manner has resulted in a dependency from many river communities for using the Missouri River as a source for domestic as well as industrial water supply. Releases have been of a uniformly good quality. There have been times when intake access becomes a problem, primarily during release reductions for flood control or because of reduced releases during extended drought. Generally, these access problems have been accommodated. The Missouri River below the System has the greater dependency on the Missouri River for its municipal water supply and thermal powerplant intakes, as indicated in Tables E-1 and E-2.

E-01.1. **Missouri River Basin – Missouri River Water Basin Intakes and Water Supply.** Water is withdrawn from the Missouri River and its System reservoirs for cooling purposes in the production of electricity; municipal water supply; and commercial, industrial, irrigation, domestic, and public uses. More than 1,600 intakes and intake facilities have been identified on the System reservoirs and river reaches (Table E-3). Of these, 302 intakes and intake facilities are identified for American Indian Tribes.

E-01.1.1. **Missouri River Basin – Upstream Water Supply Intakes.** Water supply intakes have been constructed on the System projects and river reaches downstream from several of these projects. The major population centers served are Bismarck, North Dakota and Pierre, South Dakota. The dominant category of intake type for the upstream water supply intakes is irrigation, as shown in Table E-3.

E-01.1.1.1. **Fort Peck Lake.** As shown on Table E-3, 109 water supply intakes and intake facilities are located on Fort Peck Lake. These include 1 municipal water supply facility, 5 irrigation intakes, 101 domestic intakes, and 2 public intakes. The municipal water supply facility serves a population of approximately 580 persons. Cabin owners own the majority of the domestic intakes, which are generally used in lawn watering, car washing, and fire protection. Domestic intakes along this reach are not generally used to provide drinking water, which is obtained in neighboring towns.

Table E-1
Municipal Water Supply by River Reach

Reach/Lake	Population Served	Share of Total (%)
Fort Peck Lake	580	<1
Fort Peck	28,020 (200)	1
Lake Sakakawea	21,950 (2,562)	1
Garrison	69,960	2
Lake Oahe	48,050 (11,550)	1
Oahe	0	0
Lake Sharpe	2,390 (600)	<1
Big Bend	0	0
Lake Francis Case	12,100	<1
Fort Randall	0	0
Lewis and Clark Lake	4,380	<1
Gavins Point	15,000	<1
Sioux City	88,800	3
Omaha	530,000	17
Nebraska City	0	0
St. Joseph	418,000	14
Kansas City	845,500	27
Boonville	46,740	1
Hermann	940,000	31
Total	**3,071,470 (14,912)**	**100**
Served Above Gavins Point	187,430 (14,912)	6
Served Below Gavins Point	2,884,040 (0)	94

Source: Corps, 1994 DEIS
( ) Denotes Tribal Reservation population served by municipal intakes.

Table E-2
Thermal Powerplants Using Missouri River for Cooling Water

Reach/Lake	Powerplant Gross Capacity (MW)	Share of Total (%)
Fort Peck Lake	0	0
Fort Peck	0	0
Lake Sakakawea	879	6
Garrison	3,147	21
Lake Oahe	0	0
Lake Sharpe	0	0
Lake Francis Case	0	0
Lewis and Clark Lake	0	0
Gavins Point	0	0
Sioux City	1,560	10
Omaha	2,028	13
Nebraska City	1,424	9
St. Joseph	1,026	7
Kansas City	1,309	9
Boonville	0	0
Hermann	3,711	25
Total	**15,084**	**100**
Above Gavins Point	4,026	27
Below Gavins Point	11,058	73

Source: Corps, 1994 DEIS

Table E-3
Missouri River Water Supply Intakes

Reach	River Mile	Intake by Type: Power	Municipal	Industrial	Irrigation	Domestic	Public	Total Intakes
Fort Peck Lake	1,771.6		1		5	101	2	109
Fort Peck	1,547.1		5 (1)	4	283 (94)	162 (14)	1	455 (109)
Lake Sakakawea	1,389.9	1	10 (5)	6 (1)	44 (10)	228 (63)	11	300 (79)
Garrison	1,317.4	6	3	6	77	28	3	123
Lake Oahe	1,072.3		8 (3)	2	179 (12)	21 (6)	8 (2)	218 (23)
Oahe	1,072.2							0
Lake Sharpe	987.4		3 (2)		91 (71)	19 (4)	2	115 (77)
Big Bend	987.3							0
Lake Francis Case	841.8		6		72	4	3	85
Fort Randall	836.1				100*(4)			100* (4)
Lewis and Clark Lake	811.1		2		27 (5)	6	2 (2)	37 (7)
Gavins Point	734.2		1		33	7	1	42
Sioux City	648.0	2	2	1	42 (3)		2	49 (3)
Omaha	597.2	3	2	1	8	2	5	21
Nebraska City	497.4	2			22	1		25
St. Joseph	374.0	3	4				2	9
Kansas City	249.9	5	4				1	10
Boonville	129.9		3				1	4
Hermann	0.0	3	3					6
Total		**25**	**57 (11)**	**20 (1)**	**891 (199)**	**579 (87)**	**44 (4)**	**1,616 (302)**
Above Gavins Point		7	38 (11)	18 (1)	786 (196)	569 (87)	32 (4)	
Below Gavins Point		18	19	2	105 (3)	10	12	

Source: Corps 1994
( ) Denotes intakes located on Reservation land.
* Source: Fort Randall Project Manager 2002

E-01.1.1.2. **Fort Peck Dam to Lake Sakakawea.** As shown on Table E-3, 455 water supply intakes and intake facilities are located on the Missouri River in this reach from Wolf Point to Williston. These include 5 municipal water supply facilities, 4 industrial intakes, 283 irrigation intakes, 162 domestic intakes, and 1 public intake. The municipal water supply facilities serve a population of approximately 28,020 persons, 80 percent of whom live in the Williston area. Of the 455 water supply intakes and intake facilities, there are 109 water supply intakes and intake facilities located on the Missouri River serving the Fort Peck Reservation. These include 1 municipal water supply facility, 94 irrigation intakes, and 14 domestic intakes. The municipal water supply facilities serve a population of approximately 200 persons.

E-01.1.1.3. **Lake Sakakawea.** As shown on Table E-3, 300 water supply intakes and intake facilities draw water from Lake Sakakawea. These include 1 powerplant, 10 municipal water supply facilities, 6 industrial intakes, 44 irrigation intakes, 228 domestic intakes, and 11 public intakes. The powerplant has a gross generating capacity of 879 megawatts (MW). The municipal water supply facilities serve a population of approximately 21,950 persons. Of the 300 water supply intakes and intake facilities, there are 79 water supply intakes and intake facilities that serve the Fort Berthold Reservation. These include 5 municipal water supply facilities, 1 industrial intake, 10 irrigation intakes, and 63 domestic intakes. The municipal water supply facilities serve a population of approximately 2,562 persons.

E-01.1.1.4. **Garrison Dam to Lake Oahe.** As shown on Table E-3, 123 water supply intakes are located on the Missouri River from Garrison Dam to the upper end of Lake Oahe. These include 6 powerplant intakes, 3 municipal water supply facilities, 6 industrial intakes, 77 irrigation intakes, 28 domestic intakes, and 3 public intakes. The 3 powerplants served by the 6 intakes have a gross generating capacity of 3,147 MW. The municipal water supply facilities serve a population of approximately 70,000 persons.

E-01.1.1.5. **Lake Oahe.** As shown on Table E-3, there are 218 water supply intakes are located on Lake Oahe. These include 8 municipal intakes, 2 industrial intakes, 179 irrigation intakes, 21 domestic intakes, and 8 public intakes. The municipal water supply facilities serve a population of approximately 48,050 persons. Of the 218 water supply intakes, 14 water supply intakes serve the Standing Rock Reservation. These include 2 municipal intakes, 9 irrigation intakes, 1 domestic intake, and 2 public intakes. The Reservation's municipal water supply facilities serve a population of approximately 1,550 persons. Likewise, 9 water supply intakes service the Cheyenne River Reservation. These include 1 municipal intake, 3 irrigation intakes, and 5 domestic intakes. The Reservation's municipal water supply facilities serve a population of approximately 10,000 persons.

E-01.1.1.6. **Lake Sharpe.** As shown on Table E-3, 115 water supply intakes are located on Lake Sharpe. These include 3 municipal intake facilities, 91 irrigation intakes, 19 domestic intakes, and 2 public intakes. The municipal water supply facilities serve a population of approximately 2,390 persons. Of the 115 water supply intakes, there are 22 water supply intakes serving the Lower Brule Reservation. These include a single municipal intake facility, 20 irrigation intakes, and 1 domestic intake. The municipal water supply facility serves a population of approximately 300 persons. Additionally, there are 55 water supply intakes serving the Crow Creek Reservation. These include a municipal intake facility, 51 irrigation intakes, and 3 domestic intakes. The municipal water supply facility serves a population of approximately 300 persons.

E-01.1.1.7. **Lake Francis Case From Fort Randall Dam to Lewis and Clark Lake.** As shown on Table E-3, 85 water supply intakes are located on Lake Francis Case. These include 6 municipal water supply facilities, 72 irrigation intakes, 4 domestic intakes, and 3 public intakes. The municipal water supply facilities serve a population of approximately 12,100 persons. Of the 100 irrigation intakes located on the river reach downstream of Fort Randall Dam, four are located on the Yankton Reservation.

E-01.1.1.8. **Lewis and Clark Lake.** As shown on Table E-3, 37 water supply intakes are located on Lewis and Clark Lake. These include 2 municipal water supply facilities, 27 irrigation intakes, 6 domestic intakes, and 2 public intakes. The municipal water supply facilities serve a population of approximately 4,380 persons. Of the 37 water supply intakes located on Lewis and Clark Lake, 7 are serving the Santee Reservation. These include 5 irrigation intakes and 2 public intakes.

E-01.1.2. **Missouri River Basin – Downstream Water Supply Intakes.** The lower river has 166 water supply intakes that depend on the Missouri River as their source of water.

E-01.1.2.1. **Gavins Point Reach.** As shown on Table E-3, 42 water supply intakes are located on the Missouri River below Gavins Point Dam to Sioux City, Iowa. These include 1 municipal water supply facility, 33 irrigation intakes, 7 domestic intakes, and 1 public intake. The municipal water supply facility serves a population of approximately 15,000 persons.

E-01.1.2.2. **Sioux City Reach.** As shown on Table E-3, 49 water supply intakes are located on the Missouri River in the Sioux City to Blair, Nebraska reach. These include 2 powerplant intakes, 2 municipal water supply facilities, 1 industrial intake, 42 irrigation intakes, and 2 public intakes. The two powerplants have a gross generating capacity of 1,535 MW. The municipal water supply facilities serve a population of approximately 88,800 persons. Of the 49 water supply intakes located on the Missouri River in the Sioux City reach, 1 irrigation intake is located on the Winnebago Reservation and 2 irrigation intakes are located on the Omaha Reservation.

E-01.1.2.3. **Omaha Reach.** As shown on Table E–3, 21 water supply intakes are located on the Missouri River in the Blair to Bellevue, Nebraska reach. These include 3 powerplant (one nuclear) intakes, 2 municipal water supply facilities, 1 industrial intake, 8 irrigation intakes, 2 domestic intakes, and 5 public intakes. The three powerplants have a gross generating capacity of 1,975 MW. The municipal water supply facilities serve a population of approximately 530,000 persons.

E-01.1.2.4. **Nebraska City Reach.** As shown on Table E-3, between Bellevue and Rulo, Nebraska, 25 water supply intakes are located on the Missouri River. These include 2 powerplant (one nuclear) intakes, 22 irrigation intakes, and 1 domestic intake. The two powerplants have a gross generating capacity of 1,424 MW.

E-01.1.2.5. **St. Joseph Reach.** As shown on Table E-3, 9 water supply intakes are located on the Missouri River between Rulo and Kansas City, Missouri. These include 3 powerplant intakes, 4 municipal water supply facilities, and 2 public intakes. The 3 powerplants have a gross generating capacity of 1,026 MW. The municipal water supply facilities serve a population of approximately 418,000 persons. None of 9 water supply intakes located on the St. Joseph reach of the Missouri River are on the Iowa and the Sac and Fox Reservation.

E-01.1.2.6. **Kansas City Reach.** As shown on Table E-3, 10 water supply intakes are located on the Missouri River between Kansas City and the Grand River confluence with the Missouri River. These include 5 powerplant intakes, 4 municipal water supply facilities, and 1 public intake. The 5 powerplants have a gross generating capacity of 1,309 MW. The municipal water supply facilities serve a population of approximately 845,500 persons.

E-01.1.2.6. **Boonville Reach.** As shown on Table E-3, 4 water supply intakes are located on the Missouri River between the Grand River and Osage River confluences. These include 3 municipal water supply intakes and 1 public intake. The municipal water supply intakes serve a population of approximately 46,740 persons.

E-01.1.2.7. **Hermann Reach.** As shown on Table E-3, 6 water supply intakes are located on the Missouri River between the Osage River and St. Louis. These include 3 powerplant (one nuclear) intakes and 3 municipal water supply facilities. The 3 powerplants have a gross generating capacity of 3,711 MW. The municipal water supply facilities serve a population of approximately 940,000 persons.

E-02. **Historic Municipal and Domestic Water Supply Considerations.** Missouri River water is used for municipal water supply uses. Municipal water supply use is for Tribal and public supply of water to Reservations, residents of cities and towns, and rural water districts or associations. Approximately 3 million people are served by municipal water supply facilities that withdraw water from the System and the Missouri River below the System. Tribal, public, and private water supply facilities provide treated water to households and commercial and industrial establishments. Most of the smaller municipal water supply facilities are located on the reservoirs and upper river reaches and serve about 190,000 persons. The largest municipal water supply facilities are located on the Missouri River reach below the System and serve the major urban areas of the lower basin located near the Missouri River. The municipal water supply facilities located below Gavins Point Dam serve nearly 2.9 million persons. The larger downstream municipal intakes on the Missouri River were in place well before the construction of the System. Many were in place before the turn of the century, when the cities were first established. Some of the smaller municipal or rural water supply intakes are situated at a relatively high elevation in the System reservoirs. The Corps makes every effort to accommodate serving all water intakes when it is possible to do so without impacting the other project purposes. The water supply purpose is fully served by the System because the quantity of water available has been, and is expected to continue to be, sufficient to meet the needs

E-02.1. The water supply problem that sometimes occurs is usually related to an intake access problem that is further discussed in Paragraph E-05. When these problems do occur the cost of obtaining water increases. In addition to the cost of extending intakes, costs may be incurred due to additional strain on equipment, increased sedimentation problems, and the necessity for more frequent and thorough cleaning of intake screens. Other costs include increased pumping costs, costs for additional personnel, and increases in water treatment costs to eliminate taste and odor problems that could occur from heavier algae growth at lower reservoir and river levels. Most municipalities located on the Missouri River or System reservoirs have no alternative sources of water. Some have wells that serve as short-term backup systems only. Even by instituting strict conservation measures, most facilities have only about 1 to 2 days of water supply available in storage. To increase the amount of water available, some municipalities have had to drill new wells as an alternative water source or to increase pumping capacity at existing wells.

E-02.2. Of the approximately 1,800 communities with public water service, the great majority (over 1,500) obtain their water supply from groundwater sources alone, about 200 communities use surface water sources exclusively, and 50 communities use combined surface and groundwater sources. In terms of the population served from public systems, almost 54 percent is served exclusively from surface water sources and about 35 percent is served exclusively from groundwater sources. The major cities of Omaha, Kansas City, and St. Louis, Missouri depend on the Missouri River as a major source for water supply, as do several other smaller cities along the Missouri River.

E-02.3. Currently, the gross annual withdrawal of water for municipal, rural domestic, and industrial purposes in the Missouri River basin is 2.8 million acre-feet. About 13 percent of the gross demand, equivalent to about 350,000 acre-feet annually, is consumptive use. About 21 percent of the gross demand is obtained from groundwater, 21 percent from surface water, and 58 percent from re-use of return flows from upstream systems.

E-03. **Historic Industrial Water Supply Considerations.** Many industrial water users in the Missouri River basin have water supply systems separate from the local municipal water supply systems and use both groundwater and surface water resources. Thermal-electric power generation represents the largest industrial use, with a current estimated withdrawal of over 1.7 MAF annually. Activities associated with the extraction and primary processing of ores and fuels are estimated to require almost 100,000 acre-feet each year, while other industries in the basin use about 400,000 acre-feet annually. Livestock production is an important part of the agricultural industry within the basin, accounting for about 70 percent of the average annual agricultural income. The estimated current use for livestock production is about 400,000 acre-feet annually, exclusive of evaporation from ponds constructed specifically for livestock watering purposes. Total industrial use in the basin now totals about 4 MAF annually, of which less than 1 MAF is consumptive (not returned to the tributary or main stem).

E-04. **Missouri River Basin – Irrigation Considerations.** Large Federally developed irrigation projects have not been served directly from the System reservoirs. Significant increased use of the System for irrigation water supply is not presently contemplated unless developed in association with Tribal water rights. However, approximately 100 irrigation pipeline easements have been granted to private irrigators to permit them to obtain water from the System reservoirs to serve about 40,000 acres. Numerous irrigation intakes are also located downstream from individual reservoirs and at certain times of the year their requirements have been a reservoir regulation consideration. The amount of such irrigation made possible by System regulation is not known; however, it is believed that a large amount would not have been practicable without the stabilizing influences upon river flows exerted by the regulation of the System. Table E -3 indicates almost 900 irrigation intakes either in the System reservoirs or on the Missouri with irrigation as the primary use. Historically, intake access is the major System regulation problem with serving this purpose.

E-05. **Missouri River Basin – Intake Access Problems.** Access to the water rather than the quantity of water available is the primary concern of intake operators along the Missouri River. In periods of average or above-average rainfall, few problems are experienced because river stages and reservoir levels are sufficiently high for all intakes along the Missouri River. During below-average rainfall, or drought periods, low reservoir levels and low Missouri River stages have resulted in water access problems at some intakes, causing intake owners extreme difficulties related to pumping the water. Low flows and low reservoir levels also alter sediment deposition and sandbar formation, which may further restrict the flow of water to the intakes. During the winter, ice formation can further complicate water availability, particularly in the Missouri River reaches below the System. During floods, reservoir releases are minimized, which may cause local water access problems downstream. Changes in river flows and reservoir levels affect the cost of operating intake facilities. Low water levels may increase day-to-day operating costs, or, in extreme cases, lead to capital costs for intake modification, location of an alternative water source, or even shutdowns. Low reservoir levels and below-normal reservoir releases during the recent drought forced many intake owners to modify operations and intake structures. The intent of this plan is to fully meet the authorized project purposes of water supply and providing for all irrigation requirements. The Corps will continue to make adjustments to the System to implement this purpose. However the intake access associated with obtaining Missouri River water is the responsibility of the entity choosing to use this source of water for their supply. Therefore intake access problems are the responsibility of the intake owner and the Corps will not guarantee access, only that the supply of water in the Missouri River is adequate to meet this purpose. The Corps does not assure a water supply based on a certain river stage or reservoir level, only that the quantity of water required will be available at that location. Again, accessing it is the user’s responsibility.

E-06. **Missouri River – Tribal Water Rights.** Certain Missouri River basin American Indian Tribes are entitled to water rights in streams running through and along their Reservations under the Winters Doctrine. This doctrine refers to the 1908 U.S. Supreme Court decision in the case of *Winters v. U.S.* (207 U.S. 564 1908). These reserved water rights are not forfeited by non-use. The basin's Native American Indian Tribes are in various stages of exercising their water rights. Currently, Tribal Reservation-reserved water rights have not been quantified in an appropriate legal forum or by compact, except in four instances. These are the rights embodied in the Compacts between Montana and the Tribes of the Fort Peck Reservation (awaiting Congressional approval), between Montana and the Tribes of Rocky Boys Reservation, between Montana and the Tribes of the Northern Cheyenne Reservation, and the Wyoming settlement within the Wind River Reservation. The current standard for quantification of reserved water rights where Reservations were intended for agricultural purposes is the measure of practicable irrigable acreage. There may be other standards for quantifying Tribal water rights (e.g., where a Reservation was intended to maintain viable fisheries). The standard for quantification of Tribal water rights is still evolving, however, and is not under the legal authority of the Corps. The following paragraphs discuss current and ongoing Tribal water right considerations but additional discussion is available in the Tribal Appendices of the RDEIS and FEIS.

E-06.1. The Fort Peck Compact proposal now awaiting Congressional approval would entitle the Assiniboine and Sioux Tribes of the Fort Peck Reservation to an annual diversion of 1 MAF with an annual consumptive use of 0.55 MAF. A Wyoming Supreme Court decision held that the United States, as trustee for the Shoshone and Arapahoe Tribes, was entitled to annually divert approximately 0.48 MAF of water. A divided United States Supreme Court affirmed the Wyoming Supreme Court decision without opinion.

E-06.2. The Northern Cheyenne Indian Reserved Water Rights Settlement Act (P.L. 102-374), was passed by Congress and signed by the President. This Compact allows the annual use or disposition by the Tribe of 0.03 MAF of stored water in Big Horn Reservoir in Montana per year, as measured at the outlet works of the dam or at the diversion point from the reservoir, for any purpose. The Standing Rock Sioux Tribe has indicated in correspondence to the Corps that it believes its water rights should be quantified at 1.2 MAF per year.

E-06.3. Native American reserved water rights are rights to divert water from a stream for beneficial use. When a Tribe exercises its water rights, these consumptive uses will then be incorporated as an existing depletion. Unless specifically provided for by law, these rights do not entail an allocation of storage. Accordingly, water must actually be diverted to have an impact on the operation of the System. Further modifications to System operation, in accordance with pertinent legal requirements, will be considered as Tribal water rights are exercised in accordance with applicable law.

E-06.4. Based on the survey performed by the Mni Sose Intertribal Water Rights Coalition (February 1994), the Winnebago Reservation has indicated that the System and levees "affected wetlands along the river, caused erosion, affected fishing and navigation, and caused willows to dry due to cranes." Prior to the construction of the dams and levees, the river was used for "navigation, fish, food and transportation, and willows along bank used to build wigwams, feeds, and baskets." Currently, the Tribal water sources identified in the survey are the Missouri River for agricultural uses and the aquifer/groundwater (Ogalala) for domestic uses. The Winnebago Tribe identified in the survey future water uses as "fisheries, recreation, and irrigation." Similar to the sentiments of the Santee Sioux Tribe, the Winnebago Tribe indicated in the survey that the water levels fluctuate too much and are too low. The Tribe identified "solid waste, water quality/groundwater contamination, and underground storage tanks" as its top three environmental challenges.

E-06.5. The Mni Sose Intertribal Water Rights Coalition survey indicated that, for the Omaha Reservation, the Missouri River represented "campsites, watering of livestock, fishing, watering gardens, recreation, drinking water, and trading with non-Indians" prior to the construction of the dams and levees. Construction of the dams and levees "dried Lawless Lake and Betsey Bottom Lake where cultural activities took place," caused "loss of individual allotments and Tribal lands," and moved the river, thus affecting the Tribe's sole sources of water. "Tribal ceremonies and religious activities ceased or changed," according to the survey.

E-06.6. Future water use concerns identified by the Omaha Tribe are water quality and quantity and Tribal water code by priority rights. Unlike the Winnebago Tribe, the Omaha Tribe feels that the water levels are about right and that the Reservation does benefit from the current flood control measures. Even so, the survey indicated that the Tribe feels that it would suffer a financial impact as a result of the loss of financial revenue from the alternatives previously evaluated in the RDEIS. The Omaha Tribe currently uses the Tribal Rural System (aquifer/wells system) for its water source. Additionally, the Tribe's top three environmental challenges were identified as "landfill closure, Tribal utility system, and water rights." Current land uses on the Omaha Reservation are identified as primarily agricultural, forestry, grazing, recreation, tourism, and residential, with minor amounts of commercial uses.

E-06.7. For Iowa Tribal members on the Iowa Reservation, the Missouri River was a source of "fish and fresh water" prior to the construction of the dams and levees. The survey completed by the Iowa Tribe indicated that the "fish population has declined dramatically" to "almost nonexistent" since construction of the dams and levees. Additionally, the Tribe feels that "dams and levees have caused flooding by trying to control and confine the river." The survey indicated that Tribal members feel that there is too much water level fluctuation and that the Corps should minimize the amount of fluctuation. Currently, the Tribe relies on well water as a Tribal water source and identifies recreation and irrigation as future water uses. "Solid waste, water pollution, and erosion" were identified as the top three environmental challenges facing the Iowa Tribe. Current land uses are identified as agricultural, grazing, and forestry.

E-06.8. The survey of the Sac and Fox Reservations indicated that, prior to the construction of the dams and levees, the Missouri River was a source for “navigation, hunting, and fishing.” The construction of the dams “destroyed fish and wildlife habitat,” “decreased navigation,” and “lowered creeks, affecting fishing.” The survey did not indicate any future water uses or environmental challenges for the Sac and Fox Reservation. The current identified land use on the Sac and Fox Reservation was identified primarily as agricultural.

E-07. **Missouri River Basin Depletions.** Dependence on the System as a source for water supply is continually increasing. Increases in use of the water can result in decreases in the amount of water that is available for use by those downstream from the new users. The Bureau of Reclamation (USBR) prepares estimates of the depletions of river flow for the Missouri River. The USBR also makes estimates of future levels of depletion based on projections of increased water uses along the System. The Corps uses the USBR projections and actual depletions in their forecasting and planning for System regulation.

Appendix F – Hydropower

F -01. **General.** Hydropower generation by System powerplants represents one of the authorized project purposes. The hydropower production of the System continues to be of great importance and of direct interest because of the day-by-day direct benefits realized by a large segment of the Missouri River basin's population in the form of relatively low-cost power and the annual return of very substantial cash revenues to the Treasury of the United States. Hydropower plays an important role in meeting the electricity demands of our Nation. It is a renewable energy source that helps conserve the nonrenewable fossil and nuclear fuels. It helps meet the basin's needs at an affordable price in an environmentally safe way. Nearly $6 billion in cumulative hydropower benefits amortized to current dollars has occurred from the regulation of the System. At the six System dams, 36 hydropower units provide a combined capacity of 2,435 megawatts (MW), as shown in Table F-1. These units have provided an average of 10.2 million megawatt hours (MWh) per year, or about 9 percent of the energy used in the Mid-continent Area Power Pool (MAPP) region. The MAPP region includes all of Nebraska and North Dakota; most of South Dakota and Minnesota; and portions of Montana, Iowa, and Wisconsin, as well as Manitoba and Saskatchewan in Canada. Western Area Power Administration, of the U.S. Department of Energy (Western), markets power generated at the System dams within the MAPP and Western Systems Coordinating Council (WSCC) regions.

F-01.1. The aggregate installed capacity of all powerplants in the Missouri River basin exceeds 20 thousand MW, with an annual generation of over 90 million MWh. The investor-owned systems have about 60 percent of the basin's generating capacity. The publicly owned systems consist of about 40 percent Federal hydroelectric capacity and 60 percent thermal capacity owned by non-Federal public bodies. Hydropower installations in the basin total about 3.3 thousand MW, of which about 82 percent is Federal, 14 percent is investor-owned, and 4 percent is publicly owned. The Federal power system in the upper Missouri River basin includes the six Corps System powerplants as well as the Canyon Ferry and Yellowtail powerplants constructed by the U.S. Bureau of Reclamation (USBR). Until October 1, 1977, power from all Missouri River basin Federal powerplants was marketed by the USBR. At that time, the power marketing responsibility shifted to Western. The Federal hydroelectric powerplants are connected with the extensive Federal transmission system within the USBR's Eastern Division, Pick-Sloan Missouri Basin Program, power-marketing area, which includes Montana east of the Continental Divide, North and South Dakota, eastern Nebraska, western Minnesota, and western Iowa. The transmission network is interconnected with numerous Rural Electric Association-financed cooperatives, municipal power systems, and investor-owned utilities. The Eastern Division transmission network is interconnected with the Southwestern Power Administration at Maryville, Missouri, and with the Western Division through a 100 MW D.C. tie at Stegall, Nebraska, owned by the Tri-States Cooperative. In addition, by a split-bus operation, a variable number of units can be operated on the Western System at the Fort Peck and Yellowtail (USBR reservoir project) powerplants.

F-02. **Hydropower Facilities and Historic Regulation.** The following paragraphs describe the individual System project hydropower and generation. Chapter IV in this Master Manual contains a more detailed description of the hydropower and powerplant facilities. Table F-1 presents hydropower related information for the System dams that is discussed below.

Table F-1
System Project Hydropower Data

Dam	Generator Capacity (MW)	Energy (million MWh)	Average Annual Energy Plant Factor (%)	Units	Average Gross Head (feet)	Average Flow (kcfs)	Normal Powerhouse** Capacity (kcfs)	Average Annual Flow Plant Factor (%)	Type
Fort Peck	185	1.2	74	5	200	10.1	16.0	63	Semi-Peaking
Garrison	518	2.5	55	5	173	22.8	38.0	60	Semi-Peaking
Oahe	786	2.9	42	7	181	25.4	55	46	Peaking
Big Bend	494	1.1	25	8	68	25.4	103.0	25	Peaking
Fort Randall	320	1.8	64	8	118	26.7	44.5	60	Semi-Peaking
Gavins Point	132	0.7	61	3	48	29.0	35.0	83	Baseload
Total	**2,435**	**10.2**		**36**	**788**				

** Normal powerhouse capacity is based on average reservoir elevation. Also, kcfs equals thousand cfs.

Note: Flow plant factors are calculated based on average flows versus powerhouse flow capacities. These differ from energy-based plant factors to the extent that actual plant head is less than maximum gross head.

Source: Corps, 1967-1997 actual data.

F-02.1. **Fort Peck Dam.** There are five units operating at Fort Peck Dam, with a generating capacity of 185 MW. The powerhouse discharge capacity is 16,000 cfs, and the average flow is 10,100 cfs, resulting in an average annual plant factor of 63 percent. The powerplant produces an average of approximately 1.2 million MWh of energy per year. The first hydropower unit went on line in 1943 and the first powerhouse was completed with the installation of the third unit in 1951. The second powerhouse with two units was completed in 1961. The hydropower at Fort Peck Dam is considered to be semi-peaking.

F-02.1.1. **Fort Peck Dam Releases.** Prior to 1956, Fort Peck was the only System project with a major amount of accumulated storage. As a consequence, releases in the 28,000 cfs range were frequently required for navigation purposes, with a maximum mean daily rate of 28,600 cfs in 1948. From late 1956 through early 1975, releases were never significantly in excess of the powerplant capacity of the project, amounting to about 15,000 cfs after the second powerhouse was on line. In 1975, the extremely large flood inflows to the project resulted in both maximum experienced reservoir levels and a maximum-of-record, mean-daily release of 35,400 cfs. Minimum mean daily releases since 1954 have usually been no less than 3,000 cfs; however, mean daily releases as low as 1,000 cfs have occasionally been made. Currently, the minimum release is normally 4,000 cfs, but, during drought, 3,500 cfs has been provided.

F-02.2. **Garrison Dam.** Five units operate at Garrison Dam, with a generating capacity of 518 MW. The normal powerhouse capacity is 38,000 cfs and the average flow is 22,800 cfs, resulting in an average annual plant factor of 60 percent. The powerplant produces an average of 2.5 million MWh of energy annually. The first and last power generating units were placed on line in 1956 and 1960, respectively. The Garrison powerplant is primarily a semi-peaking plant. A major rehabilitation of the Garrison powerplant was approved, and construction began in 2000 to install more efficient stainless-steel turbine runners. The switchyard may also undergo rehabilitation. The new generating capacity would be 563 MW.

F-02.2.1. **Garrison Dam Releases.** Since 1956, releases from Garrison Dam have generally been through the power facilities, having a maximum capacity of about 41,000 cfs. Exceptions were in 1975 and 1997, when outflows of 65,000 cfs and 59,000 cfs, respectively, were required to evacuate accumulated flood storage. The minimum mean daily release since 1956 has been 4,100 cfs, which occurred in 1997.

F-02.3. **Oahe Dam.** Seven units operate at Oahe Dam, with a combined generating capacity of 786 MW. The normal powerhouse capacity is 55,000 cfs. The average release is 25,400 cfs and the average annual plant factor is 46 percent. The powerplant annually produces 2.9 million MWh of energy. The hydropower units came on line in 1962 and 1963. Oahe Dam hydropower units are used to meet peaking demand patterns. This powerplant is the facility at which the electrical output is usually scheduled to follow the fluctuation in the region's load demand.

F-02.3.1. **Oahe Dam Releases.** Due to the control provided by the downstream Big Bend project, Oahe releases have been extremely variable since the project became fully operational. Minimum mean daily out flows of 1,000 cfs or less are not uncommon, while releases near the powerplant capacity of about 55,000 cfs are also frequently made. Since the powerplant became operational, nearly all releases have been made through the power turbines except during 1997, when releases were very high to evacuate a record flood.

F-02.4. **Big Bend Dam.** Eight units operate at Big Bend Dam, with a generating capacity of 494 MW. At this rating, the powerhouse capacity is 109,000 cfs. The average release is 25,400 cfs and the average annual plant factor is 25 percent, the lowest of the six System powerplants. The powerplant produces 1.1 million MWh per year. Power generating units came on line from 1964 through 1966. Big Bend Dam is primarily a peaking powerplant that normally only fluctuates through a very narrow 2-foot range in reservoir elevation.

F-02.4.1. **Big Bend Dam Releases.** Releases experienced from this project have been very similar to that described for Oahe Dam, with a maximum mean daily outflow of 74,300 cfs occurring during 1997. Releases have been entirely through the powerplant since these facilities became fully operational. A mean daily release of zero is frequently made from the project, usually on a Sunday to facilitate refilling the project for the next week's releases.

F-02.5. **Fort Randall Dam.** Eight units operate at Fort Randall Dam, with a generating capacity of 320 MW. Normal powerhouse capacity is 44,500 cfs, and the average release is 26,700 cfs. The average annual plant factor is 60 percent. The powerplant produces 1.8 million MWh per year. Power generating units came on line between 1954 and 1956. The Fort Randall Dam powerplant is a semi-peaking plant.

F-02.5.1. **Fort Randall Dam Releases**. The reservoir regulation of this project has been essentially a repetitive annual cycle. A reservoir level at or above elevation 1350 feet msl is normally maintained through the spring and summer months. During the fall period, prior to the close of the Missouri River navigation season, the reservoir is lowered to well below the base of the Annual Flood Control and Multiple Use Zone to near elevation 1337.5 feet msl. Refill of this evacuated space during the winter months results in increased hydropower generation during the winter period and compensates for the reduced winter releases from Fort Randall and Gavins Point Dams that are scheduled to reduce the downstream flood risk. The winter period experiences increased downstream flood risk because of a reduction in channel capacity due to river ice formation. A maximum release of 67,500 cfs occurred in 1997. A maximum pool elevation of 1372.2 feet msl occurred in 1997.

F-02.6. **Gavins Point Dam.** Three units operate at Gavins Point Dam, with a generating capacity of 132 MW. These units came on line in 1956 and 1957. The powerhouse capacity is 35,000 cfs, and the average release is 29,000 cfs. The average annual plant factor is 83 percent, which is the highest of the six System powerplants. The powerplant produces 0.7 million MWh of energy per year. Gavins Point is the only dam that is not operated to provide peaking power. Generally, daily releases from Gavins Point Dam are constant to allow for stable downstream navigation and other project purposes.

F-02.6.1. **Gavins Point Dam Releases.** Since full regulation began, the reservoir has usually been regulated in the narrow zone extending from elevation 1204.5 feet msl to elevation 1208 feet msl. A maximum reservoir level of 1210.7 feet msl occurred in1960. Since the System filled in 1967, a maximum of 1209.5 feet msl was attained in 1995. Also, Lewis and Clark Lake was drawn down to elevation 1199.8 feet msl in 1969 in anticipation of large amounts of inflow from plains snowmelt. Minimum mean daily releases from the project have been about 5,000 cfs and maximum releases of 70,000 cfs were made in 1997.

F-03. **Benefits of Hydropower.** The System powerplants provide three principal hydropower benefits. First, by providing dependable capacity to meet annual peak power demands; System hydropower helps ensure the reliability of the electrical power system in MAPP. This reduces the need for additional coal, gas, oil, or nuclear generating capacity. Second, the six powerplants provide a large amount of energy at a very small cost relative to thermal electric generating stations, reducing the overall cost of electricity. Hydropower facilities reduce the burning of fossil fuels, thereby reducing air pollution, acid rain, and the greenhouse effect. Finally, hydropower has several valuable operating characteristics that improve the reliability and efficiency of the electric power supply system, including efficient peaking, a rapid rate of unit unloading, and rapid power availability for emergencies on the power grid.

F-03.1. **System Hydropower Generation Considerations.** Power generation at the six System dams generally must follow the seasonal pattern of water movement through the System. Adjustments, however, have been made to the extent possible to provide maximum power production during the summer and winter months when demand is high. Oahe and Big Bend power generation is relatively high during the winter. Since System release in the winter is low, the winter Oahe and Big Bend powerplant releases must be stored in Lake Francis Case. To allow for this, Lake Francis Case is drawn down during the fall of each year, as discussed in the following paragraphs.

F-03.2. Hourly patterning of the average daily releases is also of major importance in realizing the full power potential of the System powerplants. Based on past experience with both open water and a downstream ice cover, in most cases no limits need be placed upon daily peaking (with the exception of Gavins Point) up to the capacities of the individual powerplants, provided the limiting mean daily discharge is not exceeded. The Gavins Point project is normally flat loaded with very little hourly release variation. Should daily peaking at this project be required for a limited time, a limit on hourly variations in discharge is normally imposed to the extent that cumulative releases will not depart more than 10 percent of the total daily release from a flat schedule. Once an ice cover forms on the Missouri River, the Gavins Point Dam release is normally scheduled at a flat release rate to minimize the potential risk to ice-jam flooding downstream. The peaking capability of this project during the winter months is normally limited to the capability of just two units as the other unit is undergoing maintenance. The minimum allowable hourly generation, and corresponding release, is dependent upon the hydraulic characteristics of the river below each of the projects and the effect upon water use in the downstream reaches. Downstream water supply intakes, fish spawning activities in the downstream channel, recreational usage, and other factors that may be seasonal in nature influence the selection of minimum limits. These constraints at particular projects are summarized in this Master Manual and discussed in more detail in the appropriate individual System project water control manuals.

F-03.3. In addition to hourly patterning, it is possible, due to the flexibility inherent in such a large System of reservoirs, to pattern project releases (with the exception of Gavins Point Dam) to cycles extending for periods longer than a day in duration for maximum power production while still providing full service to the authorized project purposes other than hydropower. During the navigation season when downstream flow requirements are high, large amounts of water are normally released from Gavins Point Dam. This requires that large volumes of inflow to Gavins Point be supplied from Fort Randall. Fort Randall, in turn, requires similar support from Big Bend, and Big Bend from Oahe. Here the chain can be interrupted because Oahe is large enough to support high upstream releases for extended periods without correspondingly high inflows. High summer releases from Gavins Point, Fort Randall, Big Bend, and Oahe Dams mean high generation rates at these plants. To avoid generating more power than can be marketed advantageously under these circumstances and to provide more winter hydropower, the usual practice during this time of year is to hold releases and generation at Fort Peck and Garrison Dams at lower levels unless the evacuation of flood control storage space or the desire to balance storages between projects becomes an overriding consideration. With the end of the navigation season, conditions are reversed. Releases from Gavins Point Dam drop to about one-fourth to one-half of summer levels and the chain reaction proceeds upstream, curtailing releases from Fort Randall, Big Bend, and Oahe Dams. At this time, Fort Peck and Garrison Dam releases are usually maintained at the maximum levels permitted by the downstream ice cover to partially compensate for the reduction in generation downstream.

F-04. **System Hydropower Capacity and Energy.** The hydropower generating capacity that is available from the System dams at any time varies with the water-surface elevations of the reservoirs (“head” on the units). As the reservoir elevations fall during long-term droughts, the generating capacity (capability) of the System is decreased. During the 1987 to 1993 drought, power production fell sharply. In 1992, lower reservoirs levels and reduced releases resulted in power production at 65 percent of normal. Power production in 1993 was even lower due to a significant reduction in System releases for an extended period of time for a major downstream flood control effort. The current drought has also limited power production to 75 percent of normal in 2003.

F-04.1. The dependable capacity, as currently marketed by Western, is based on the potential reoccurrence of the 1954 to 1961 drought conditions. At the time, the Corps determined that the System dams could provide this amount of capacity or more about 85 percent of the time. Based on conditions that were estimated to exist in 1961 following 8 years of drought and 1990 depletion levels, about 2,070 MW and 2,010 MW of dependable capacity are available during summer and winter seasons, respectively. Western will update the dependable capacity based on data provided in the CWCP in this Master Manual.

F-04.2. The two major components that determine hydropower value are capacity and energy values. For hydropower, maximum value is achieved when the capacity and energy outputs are maximized. The capacity value reflects the ability of the hydropower units to provide capacity when needed, especially during summer and winter peak demand periods. With potential reduced dependable capacity during these time periods, alternative generation facilities would need to be constructed beyond those currently planned over the next decade or two to avoid potential brownouts or blackouts.

F-04.2.1. Capacity. The value of power produced at a particular powerplant is greatest when the available capacity is maximized. This occurs when the available head is a maximum. For most plants, this condition occurs when the reservoir is at its maximum elevation. As the reservoir elevation drops, the head decreases, and the capacity value drops proportionally. Because sufficient water must be released to make the capacity available through the peak demand period, capacity benefits are also a function of the project’s release.

F-04.2.2. Energy. The value of the energy produced varies from season to season, depending on water conditions and the power demand, but normally the higher the demand, the greater the value of hydropower. Because demand is greatest in summer and winter, energy produced during these seasons is of greater overall value than energy produced in the spring and fall. In general, the energy value represents the value of hydropower that minimizes the cost of operating all available plants (hydropower plus thermal) to meet day-to-day power demand. This value is greatest when the hydropower units have sufficient water to produce a maximum amount of energy.

F-04.2.2.1. The value of the energy produced by a particular powerplant during a month is generally maximized when the powerplant produces as much energy as possible. Because hydropower units burn no fuel, the cost of production is very low, about $10 per MWh. When hydropower is available, generation from more expensive coal or oil-burning plants can be reduced. The savings hydropower provides depends on the value of the thermal energy it displaces and the amount of hydropower produced. Hence, the true energy value to the consumer is the per-unit cost of the thermal energy displaced.

Appendix G – Navigation

G-01. **Navigation Background.** The Missouri River Bank Stabilization and Navigation Project (BSNP) was designed to prevent bank erosion and channel meandering and to provide reliable commercial navigation on the Missouri River. This project, authorized by Congress in the Rivers and Harbors Act of 1945, is designed to secure a permanent, continuous, open-river navigation channel with a 9-foot depth and a width of not less than 300 feet under full navigation service conditions for a distance of 735 miles from near Sioux City, Iowa to the mouth near St. Louis, Missouri. Construction of the navigation works was declared complete in September 1981, although corrective work will be required as the Missouri River continues to form its channel in response to changing flow conditions. The navigation project is not accomplished by using locks, as is the case on most of the inland waterway systems, but by using river structures placed to confine and control the channel. The use of these structures produces velocities high enough to prevent the accumulation of sediment in the channel and permits an open river channel condition for the entire length of the project. Maintenance of these dimensions, however, requires releases from the System and some infrequent dredging activities, particularly during periods of sub-normal water supply. The velocities in the Missouri River are higher than on other inland navigation systems, which can present challenges to navigating the river. This navigation project is an important link with the Mississippi River waterway system. Low-cost transportation, particularly for bulk commodities, is available at many localities in the Missouri River valley. Cities and commercial interests have provided facilities along the banks of the river for both handling and managing navigation traffic.

G-01.1. Major commodities transported on the Missouri River include agricultural products (farm and food products); chemicals, including fertilizers; petroleum products, including asphalt; manufactured goods, including building products such as cement; and crude materials such as sand, gravel, and materials used to maintain the Missouri River BSNP. Commercial tonnage, which excludes sand and gravel and waterway materials, peaked in 1977 at 3.3 million tons and has generally declined since then. Total tonnage continues to set records. Table G-1 presents annual tonnage of commodities transported on the Missouri River during those years shown.

G-01.2. Commercial tonnage moves throughout the entire navigation season, but tends to peak in the spring and fall. The state of Missouri is typically an origin or destination for over half of Missouri River commercial tonnage. The Port of Kansas City serves as an origin or destination for about one-third to as much as one-half of Missouri River commercial tonnage. Up-bound movements of commercial products have recently exceeded down-bound movements by as much as two-to-one. This is a reversal of the predominant direction of product movement from earlier decades of Missouri River navigation, when grain movements from the Midwest were more dominant. Approximately 90 percent of Missouri River commercial tonnage is also moved on the Mississippi River. About 120 docks and terminals are located on the lower Missouri River. Approximately one-half of these are located near and downstream of Kansas City, about 26 percent in the reach from Nebraska City and to Kansas City, about 11 percent in the reach from Omaha to Nebraska City, and about 10 percent from Sioux City to Omaha.

Table G-1
Missouri River Navigation Freight Traffic
(thousands of short tons)

	Year						
Commodity	**1940**[a/]	**1950**[a/]	**1960**	**1970**	**1980**	**1990**	**2000**[c/]
Farm Products	53.2	79.9	1,061.3	1,059.0	1,099.8	371.0	488
Corn			59.5	143.8	87.8	32.0	198
Wheat			649.1	669.0	835.2	171.0	21
Soybeans			104.9	208.8	164.1	40.0	153
Nonmetallic Minerals	330.0	282.9	1,495.3	2,869.5	2,855.4	4,268.0	7,254
Sand/Gravel	330.0	282.9	1,462.1	2,677.5	2,715.2	4,240.0	7,225
Food and Kindred			135.5	370.3	570.8	61.0	42
Pulp and Paper			0.0	16.7	3.6	6.0	1
Chemicals	0.5	0.8	21.3	526.2	501.8	345.0	289
Fertilizer			11.3	460.2	455.9	312.0	281
Petroleum	46.5	3.5	17.2	50.4	315.6	345.0	256
Stone/Clay/Glass			0.0	157.7	146.7	154.0	163
Primary Metals	6.3	58.5	164.8	57.8	95.4	11.0	69
Waterway Materials	844.8	1129.5	4,045.8	2,377.2	290.3	272.0	165
Other	15.2	54.4	7.7	34.4	35.4	8.0	6
Total	**1,296.5**	**1,609.5**	**6,948.9**	**7,519.2**	**5,914.8**	**5,841.0**	**8,733**
Total Commercial [b/]	121.7	197.1	1,441.0	2,464.5	2,909.3	1,329.0	1,343.6

a/ Commodity category definition is slightly different before 1960.
b/ Commercial excludes sand and gravel and waterway materials.
c/ Data Source: Waterborne Commerce of the U.S.
Source: Navigation Economics Technical Report (Corps).

G-02**. Historic Service Level Considerations.** The explanation of the use of service level to serve the authorized System project purposes is contained in Chapter VII, paragraph 7-03.2 of this Master Manual. The difference between minimum and full-service flow support is 6,000 cfs. The minimum service level of downstream flow support allows an 8-foot depth in the Missouri River navigation channel. The full-service level of downstream flow support allows a 9-foot depth in the Missouri River navigation channel. The selection of the service level is based on criteria explained in Chapter VII, paragraph 7-03.2.1.1. The season length is based on a System water-in-storage check and is presented in Chapter VII, paragraph 7-03.4 of this Master Manual. The season length and service level are the basis for determining the quantity of water provided during the open-water season to meet the Congressionally authorized System project purposes served below the System. The CWCP serves the navigation purpose through the service level and season length criteria discussed earlier in Chapter 7. Operating experience has demonstrated that the flows for full-service navigation are 31,000 cfs at Sioux City and Omaha, Nebraska; 37,000 cfs at Nebraska City, Nebraska; and 41,000 cfs at Kansas City, Missouri. These full-service flows generally provide the authorized 9-foot navigation channel, and they allow the capability to load barges to an 8.5-foot draft. Flows that are 6,000 cfs lower are provided for the designated minimum service. These flows generally provide a minimum 8-foot channel, and barges can be loaded to a 7.5-foot draft. Commercial navigation declines or ceases at flows below the minimum service level of 8 feet. At minimum service, flows are generally adequate to provide the indicated drafts, but a considerable amount of time and profit is lost due to bumpings and groundings.

G-02.1. Based on actual experience, minimum downstream flows that permit satisfactory navigation on the Missouri River are 25,000 cfs at Sioux City and Omaha, 31,000 cfs at Nebraska City, and 35,000 cfs at Kansas City. When these minimum flow levels occur, dredging could be required to maintain a satisfactory navigation channel, and a relatively high incidence of groundings and bumpings can be expected. With the present level of streamflow depletions, inflows into the System are sufficient to support these minimum flow levels or higher in about 3 out of 4 years without any loss of water in storage. When System water reserves are adequate, navigation flows are generally above the minimum service levels. This will result in decreased dredging requirements and can also result in barge loadings to greater depths than would be possible with minimum service flows.

G-02.2. In higher runoff years when water accumulated in the Annual Flood Control and Multiple Use Zone is being evacuated, release rates that slightly exceed full service levels provide some additional benefit to navigation and also benefit System hydropower production. Scheduling System releases in this range is preferable to delaying releases and running the risk of having to increase releases to levels that exceed powerplant capacity and provide no increased benefit to navigation. Table G-2 indicates downstream service levels that have been provided since the System filled in 1967.

G-03. **Historic Season Length Considerations.** In years with near-normal runoff into the System, the navigation season is normally supported for 8 months from April 1 to December 1 at the mouth of the Missouri River. During past navigation seasons with above-normal water in the System, 10-day extensions, either before or after a normal season were scheduled, Missouri River conditions permitting. Extensions and attempted extensions prior to the normal opening dates of the navigation season were, however, found to be unsatisfactory. In many years, the ice cover below Gavins Point Dam was still in place at the time it was necessary to schedule increased releases from the System to provide the extension, which prohibited the early opening because of the downstream flood risk. Additionally, in those years when earlier-than-normal navigation releases are possible, experience has indicated that towboat groundings during this early period are much more frequent than during the remainder of the season. The increased incidence of groundings appears to be related to the cold water temperatures and their effect on channel topography. Although early opening of the navigation season is faced with problems, market conditions favor early transport of grain, fertilizer, and other commodities on the river, and dam releases necessary to provide satisfactory depths are generally much smaller than for a fall extension. Provision of an early opening will, therefore, continue to be explored, as conditions warrant. With an adequate amount of water in the System, consideration will also be given to extensions beyond the normal closing date. The shortening of the season for water conservation purposes is considered preferable to reducing releases below what are considered minimum service levels. Shortening of the season in these extended drought periods is done in accordance with the criteria in Table VII-3 of this Master Manual. The season lengths provided historically and the tonnages moved in each year since the System first filled in 1967 are shown in Table G-3.

Table G-2
Historic Open-Season Target Flows
(1,000 cfs)

Year	Months	Sioux City	Omaha	Nebraska City	Kansas City
1967	Apr-Jun	28.0	28.0	34.0	38.0
	Jul-Nov	31.0	31.0	37.0	41.0
1968	Apr-Nov	31.0	31.0	37.0	41.0
1969	Apr-Jun (1)	35.0-40.0	35.0-40.0	41.0-46.0	45.0-50.0
	Jul (1)	36.0	36.0	42.0	46.0
	Aug-Sep (1)	50.0-55.0	50.0-55.0	55.0-60.0	55.0-60.0
	Oct-Nov (1)	40.0-45.0	40.0-45.0	45.0-50.0	50.0-55.0
1970	Apr-May	31.0	31.0	37.0	41.0
	May-Sep (1)	36.0	36.0	42.0	46.0
	Oct-Nov (1)	40.0	40.0	46.0	50.0
1971	Apr-May (1)	36.0	36.0	42.0	46.0
	May-Nov (1)	45.0-50.0	45.0-50.0	50.0-55.0	55.0-60.0
1972	Apr-Nov (1)	40.0-50.0	40.0-50.0	45.0-55.0	50.0-60.0
1973-74	Apr-Nov	31.0	31.0	37.0	41.0
1975	Apr	31.0	31.0	37.0	41.0
	May-Nov (1)	35.0-60.0	35.0-60.0	41.0-66.0	45.0-70.0
1976	Apr-Jul (1)	34.0-38.0	34.0-38.0	40.0-44.0	44.0-48.0
	Aug-Dec (1)	31.0-34.0	31.0-34.0	37.0-40.0	41.0-44.0
1977	Apr-Nov	31.0	31.0	37.0	41.0
1978	Apr	31.0	31.0	37.0	41.0
	May-Jul (1)	35.0-46.0	35.0-46.0	41.0-52.0	45.0-56.0
	Aug-Nov (1)	46.0-51.0	46.0-51.0	52.0-57.0	56.0-61.0
1979	Apr-Jul (1)	36.0-42.0	36.0-42.0	42.0-48.0	46.0-52.0
	Aug-Nov (1)	31.0-36.0	31.0-36.0	37.0-42.0	41.0-46.0
1980	Apr-Nov	31.0	31.0	37.0	41.0
1981	Apr-Nov (2)	31.0	31.0	37.0	41.0
1982	Apr-Sep	31.0	31.0	37.0	41.0
	Oct	31.0-36.0	31.0-36.0	37.0-42.0	41.0-46.0
	Nov-Dec (1)	36.0-46.0	36.0-46.0	42.0-52.0	46.0-56.0
1983	Apr-Jun	31.0	31.0	37.0	41.0
	Jul	31.0-36.0	31.0-36.0	37.0-42.0	41.0-46.0
	Aug-Nov (1)	36.0	36.0	42.0	46.0
1984	Apr-Jun	31.0	31.0	37.0	41.0
	Jul-Dec (1)	31.0-44.0	31.0-44.0	37.0-50.0	41.0-54.0
1985	Apr-Dec	31.0	31.0	37.0	41.0
1986	Apr (1)	36.0-41.0	36.0-41.0	42.0-47.0	46.0-51.0
	May-Dec (1)	41.0-46.0	41.0-46.0	47.0-52.0	51.0-56.0
1987	Apr-Nov	31.0	31.0	37.0	41.0
1988	Apr-Nov (2)	31.0	31.0	37.0	41.0
1989	Apr-Aug (3)	28.0	28.0	34.0	38.0
	Sep-Oct (3)	28.0	28.0	34.0	35.0
1990-93	Apr-Oct (4)	25.0	25.0	31.0	35.0
1994	Apr-Dec	31.0	31.0	37.0	41.0
1995	Apr-May	31.0	31.0	37.0	41.0
	Jun-Dec (1)	46.0-56.0	46.0-56.0	52.0-62.0	56.0-66.0
1996	Apr (1)	41.0	41.0	47.0	51.0
	May (1)	41.0-51.0	41.0-51.0	47.0-57.0	51.0-61.0
	Jun-Dec (1)	56.0	56.0	62.0	66.0
1997	Apr - Dec (5)	*	*	*	*
1998	Apr - Dec	31.0	31.0	37.0	41.0
1999	Apr-Dec (1)	31.0-43.0	31.0-43.0	37.0-49.0	41.0-53.0
2000	Apr-Jun	31	31	37	41
	Jul-Dec (3)	29.5	29.5	35.5	39.5
2001	Apr-Dec (3)	28	28	34	38
2002	Apr-Jun (3)	27	27	33	37
	Jul-Dec (3)	25	25	31	35
2003	Apr-Nov (4)	25	25	31	35

(1) Downstream flow targets above full-service navigation level as a flood control storage evacuation measure.
(2) Full-service flows provided for shortened season.
(3) Navigation targets below full service as a water conservation measure.
(4) Navigation targets at minimum service as a water conservation measure.
(5) Releases determined by flood control storage evacuation criteria and not to meet specific navigation targets.

Table G-3
Missouri River Navigation
Tonnage and Season Length

Year	Scheduled Length of Season (Months)	Commercial (Tons) (1)	Total Traffic (Tons) (2)	Total Traffic (1000 Ton-Miles) (1)
1967 (3)	8	2,562,657	6,659,219	1,179,235
1968	8 (4)	2,254,489	6,724,562	1,047,935
1969	8 (4)	2,123,152	7,001,107	1,053,856
1970	8 (5)	2,462,935	7,519,251	1,190,232
1971	8 (4)	2,791,929	7,483,708	1,329,899
1972	8 (4)	2,665,579	7,182,841	1,280,385
1973	8	1,817,471	6,370,838	844,406
1974	8	2,576,018	7,673,084	1,227,525
1975	8 (4)	2,317,321	6,208,426	1,105,811
1976	8 (4)	3,111,376	6,552,949	1,535,912
1977	8	3,335,780	6,734,850	1,596,284
1978	8 (4)	3,202,822	7,929,184	1,528,614
1979	8 (4)	3,145,902	7,684,738	1,518,549
1980	8	2,909,279	5,914,775	1,335,309
1981	7-1/4 (6)	2,466,619	5,251,952	1,130,787
1982	8 (4)	2,513,166	4,880,527	1,131,249
1983	8 (4)	2,925,384	6,301,465	1,300,000
1984	8 (4)	2,878,720	6,386,205	1,338,939
1985	8 (4) (7)	2,606,461	6,471,418	1,201,854
1986	8 (4) (7)	2,343,899	6,990,778	1,044,299
1987	8	2,405,212	6,735,968	1,057,526
1988	7-1/2	2,156,387	6,680,878	949,356
1989	6-3/4	1,906,508	5,352,282	796,799
1990	6-3/4	1,329,000	5,841,000	552,509
1991	6-3/4	1,563,000	5,729,000	
1992	6-3/4	1,403,000	5,783,000	
1993	8 (8)	1,570,000	5,631,000	615,541
1994	8	1,800,000	8,501,000	774,491
1995	8 (4) (8)	1,439,000	6,884,000	604,171
1996	8 (4)	1,547,000	8,165,000	680,872
1997	8 (4)	1,651,000	8,172,000	725,268
1998	8 (4)	1,735,000	8,379,000	777,727
1999	8 (4) (8)	1,576,000	9,252,000	699,744
2000	8	1,344,000	8,733,000	628,575
2001	8	1,288,000	9,732,000	566,150
2002	8 (9)	1,100,000	8,270,000	
2003	8 (10)	1,101,000 (11)		

(1) Includes commercial tonnage except for sand and gravel or waterway materials. Tonnage compiled by Waterborne Commerce Statistics Center (WCSC).
(2) Includes commodities; sand, gravel and crushed rock; and waterway improvement materials. Tonnage by WCSC.
(3) Mainstem reservoir system reached normal operating storage level in 1967.
(4) Ten day extension of season provided.
(5) Ten day extension and 10-day early opening provided.
(6) Full-service flows for shortened season in preference to reduced service.
(7) Ten day extension provided for 1985 season in trade for 10-day delayed support of 1986 season.
(8) Lower Missouri River closed 57 days in 1993, 20 days in 1995, and 18 days in 1999.
(9) The Corps did not support navigation from July 3 to August 14, 2002 to protect T&E Species blw Gavins Point.
(10) Six day shortening of season to follow CWCP. From August 11 to September 1, 2003, the Corps did not support navigation flows to comply with lawsuit to follow 2000 Biological Opinion.
(11) Preliminary estimate.

G-04. **Navigation Season Shortening Versus Reduced Service Level Modification.** Shortening of the normal 8-month navigation season since the System first filled in 1967 occurred in 1981, 1988 to 1992, and 2003. Navigation flows in 1981 were maintained at full service although the July 1 System storage check called for a 2,000 cfs reduction in service level. Shippers and river users expressed their desire for a shortened season instead of less-than-full-service flows with corresponding stage reductions. The 1981 season was shortened 3 weeks to compensate for the extra volume of water used to provide full-service flows.

G-04.1. Full-service support to navigation was provided in the spring of 1988, which is consistent with the March 15 storage check. The July 1 storage check called for a 3,000-cfs-less-than-full-service (intermediate service) release; however, affected river interests opted for continued full-service support with a shortened season, as was first provided in 1981. Navigation target flows were not met from mid-June through August due to release restrictions for endangered species nesting. The 1988 navigation season was shortened 2 weeks as a water-volume adjustment. With the continuation of the drought into 1989, the March 15 storage check called for minimum service for the entire navigation season, but intermediate service releases were made with a 5-week shortened season as a System storage water volume adjustment. Minimum service flows with a 5-week shortened season were provided for the duration of the drought (1990 through 1992). Gavins Point Dam releases were "cycled" every third day from mid-May to August in 1990, 1991, and 1992 to conserve water in System storage yet permit release increases later in the summer. The 1979 Master Manual criteria did not shorten the season until July 1 System storage was less than 41 MAF, but additional conservation measures were implemented beginning in the 6-year drought period from 1987 to 1993. Regulation experience showed that additional water conservation measures beyond the specific technical criteria published in the1979 Master Manual could be required if System storage was below 52 MAF on July 1 of any year. These additional conservation measures were used when needed during drought to offset increased release requirements for water supply due to degradation of the channel bed and to serve navigation while meeting the Corps' obligations, in consultation with the U.S. Fish and Wildlife Service (Service) under the Endangered Species Act (ESA).

Appendix H – Continuing Studies

H-01. **Introduction.** This appendix presents and discusses the areas related to the regulation of the System that are candidates for continuing studies. The Corps recognizes that the regulation of the System under the CWCP may not be appropriate in the future. It is impossible to foresee the future sequences of floods and droughts; future regulation requirements for threatened and endangered species; the time and conditions under which water conservation measures may be implemented on tributaries and their effects on streamflow; the future amounts of flow depletions, whether by the implementation of Tribal water rights or by other factors; changes in power market characteristics; changes in future water requirements for navigation; and possible changes in emphasis on one primary purpose or another with changing national policies and economic conditions. Studies could, however, be undertaken, when appropriate, for improvement of the methods of regulation proposed in this Master Manual using fairly firm forecasts of future development.

H-02. **Forecasting Techniques and Procedures.** As the demand for water supply continues to increase, the value of water stored in the System will also increase proportionately. If future flows could be accurately known sufficiently in advance, a reduction in the amount of the storage space specifically set aside for flood control purposes could be accomplished such that the storage could be distributed to increase the benefits to the other authorized purposes. Due to the inability to completely anticipate future events, such procedures are not possible at this time; however, it is evident that any indication of future flood events within the basin could lead to an improved System regulation. The more accurately and further in advance that runoff can be forecasted, the greater will be the benefits derived from adjustments to System regulation. For this reason, major emphasis has been placed on continuing studies designed to improve forecasts of streamflow, both into the System and into the Missouri River below the System. Integration of National Weather Service (NWS) Multi-sensor Precipitation Estimate (MPE) data with current streamflow forecasts, as discussed in detail in Chapter 6 of this Master Manual, is an example of near real-time improvement in streamflow forecasting that is currently being implemented.

H-03. **Optimum Evacuation Schedules.** Flood storage evacuation following a major flood runoff into the System may be accomplished at rates greater than required for conservation purposes to ensure that adequate space is available for the control of future flood events. This evacuation should be made in an orderly manner that will ensure the maximum beneficial use of the stored water and should minimize the risk of contributing to damaging flows in the lower reaches. Sufficient water in storage in the Annual Flood Control and Multiple Use Zone should be retained to provide for optimum conservation regulation through subsequent low-flow periods insofar as consistent with future flood control regulation. Evacuation schedules will be evaluated, when appropriate, through additional studies. For example, the development of more accurate plains snowmelt runoff models can lead to the earlier pre-release of water in storage prior to large flood events, which could allow the System to further reduce flood damages.

H-04. **Tributary Development.** Several different categories of future development on the tributaries will affect the System that, when appropriate, need appraisal. The amount of storage available for flood control in tributary reservoirs or how the regulation of these reservoirs may change, could lead to effects on System regulation. Additional evaluation of these changes is also essential for estimating flood control benefits to be assigned to tributary reservoirs. Effects of soil conservation and forestry practices on flood flows and water yields may also need further appraisal. The growth of privately developed irrigation pumping on some tributaries may affect the water yield to the point during future low water years that future RCC studies may be needed to assess the effect on System regulation.

H-05. **Channel Characteristics.** The channel characteristics of the Missouri River, such as channel capacities, water travel times, and ice formation, will need to be the subject of continuing studies insofar as changes to them affect System regulation. The results of changes in the flow regimen caused by System and tributary reservoir development can be fully determined only through continuous observation and study. While most channel and adjacent improvements, such as channel realignments, bank stabilization, and levee construction, have already occurred that could substantially affect System regulation, channel capacity changes continue to occur. Studies relating to the maximum permissible flow rates under ice-cover conditions should be continued. Any change in the estimated capacities would be of importance not only from the standpoint of flood control but also from the standpoint of winter power generation. Also, downstream Missouri River degradation has increased channel capacity in some reaches. Conversely, aggradation has reduced the channel capacity in other reaches. The effects of these changes need continued monitoring and study.

H-06. **Sedimentation.** The Missouri River normally carries a great sediment load through its entire length. Reservoirs cause reduced velocities, and most of the sediment originating upstream from the System will be deposited in the reservoirs. Theoretical studies and field surveys of the sediment deposition in the individual reservoirs have been historically made to track the manner and amount of deposition. These studies will be corroborated by continuing observations of actual deposition in the reservoirs. Sediment ranges for this purpose have been established in each of the reservoirs, as described in the individual project manuals. Continuing studies relative to the distribution of the space in each of the storage zones will take into consideration storage space that may be lost to sediment deposition.

H-07. **Channel Degradation.** A problem somewhat similar to sedimentation within the reservoirs will be that of channel degradation below the dams. The anticipated degradation below each project was taken into account when establishing the elevation of stilling basins and draft tubes. Continuing surveys of channel degradation will be made so that its extent may be defined. If necessary, remedial measures may be taken to ensure the maximum economic return from power production of the project. Channel degradation has also resulted in adverse impacts to the Missouri River below the System. The primary impact is due to the shortening of the Missouri River to create a more navigable channel. The channel shortening has resulted in the loss of oxbow and chute habitat for the native fishery. One positive affect of channel degradation is an increase in carrying capacity of the Missouri River in some reaches. This additional capacity results in additional damages prevented during periods when evacuation of water from major runoffs has occurred. Potential effects of degradation in some of the lower river reaches need to be studied so water supply interests can plan for future Missouri River access.

H-08. **Flood Control Storage Zone Allocations.** As discussed in Appendix A, the storage allocations used in this Master Manual have gone through a long history of analysis over time and have been changed slightly, primarily the result of the aggradation that has occurred in the reservoirs. The CWCP has not substantially changed the storage zone elevations but has resulted in some changes primarily to the Carryover Multiple Use Zone. The Annual Flood Control and Multiple Use Zone and the Exclusive Flood Control Zone have been examined and determined to be adequate to meet the flood control objective of this manual. Futures studies will be conducted, as warranted, to examine the storage zone allocations. These studies are necessary not only for the definition of total System flood control at locations but also for the optimum distribution of the total flood control storage included in reservoirs comprising the System. In these studies, consideration should be given to the effects of present tributary reservoir development, including the effects of those projects with specifically allocated flood control space and those projects regulated entirely for conservation purposes. Depletions to streamflow resulting from evaporation on System and tributary reservoirs, irrigation, implementation of Tribal water rights, conservation practices in the basin, and development of the multitude of stock and farm ponds will also be considered. With these and other considerations, as may be deemed appropriate, design inflows to the System and each reservoir comprising the System will be developed on the basis of past flood history and the flood potential of the basin.

H-09. **Release Restrictions.** Restrictions on releases from individual reservoirs affecting flood control considerations will be analyzed in greater detail. Studies concerning evacuation schedules and channel characteristics, as discussed earlier in this appendix, will be necessary. Restrictions imposed by the downstream flood potential will be further evaluated. Consideration will also be given to necessary service to authorized purposes other than flood control that must be maintained at the time of flood control regulation.

H-10. **Design Flood Storage.** With the detailed analysis of design flood inflows to the System and permissible releases from the System during the inflows, the storage required for control of the design flood could be re-examined. Such determination will take into account allocations for both seasonal and exclusive flood control functions and their corresponding differing regulation criteria. This could lead to the redistribution of the storage space between the Permanent Pool Zone and the base of required surcharge storage in each System reservoir.

H-11. **Ongoing Basin Development.** As basin development continues, further analysis will need to be made of developed storage at all locations. Other continuing studies, as discussed in this appendix, will also have a bearing on the analysis. Only, by keeping current with developments and making appropriate adjustments in reservoir regulating procedures and allocations, can the full potential benefits of the System be realized. An anticipation of future development with associated studies is also essential, not only for orderly long-range planning of System regulation but also for planning tributary reservoir regulation and future benefits evaluations. Consequently, the Corps envisions that periodic reanalysis of System storage distribution will be necessary.

H-12. **Other Studies.** The update for this Master Manual was studied in detail since the update commenced in 1989. Many alternatives were evaluated and shared with the public during this process. Those alternatives showing promise were evaluated with a determination of benefits calculated. This information is documented as part of the environmental impact statement (EIS) public process and will not be presented here. The CWCP provides the best solution to meeting the objectives established as the Preferred Alternative was chosen for the Final EIS and the selected plan chosen as the CWCP for the regulation of the System and Missouri River.

H-13. **The Upper Mississippi River System Flow Frequency Study**. The Upper Mississippi River System Flow Frequency Study (UMRS FFS) was completed in 2003. Study participants were the Corps (HQUSACE, IWR, MVD, NWD, MVP, MVR, MVS, NWK, NWO), U.S. Geological Survey, National Weather Service, U.S. Bureau of Reclamation, Natural Resources Conservation Service, Federal Emergency Management Agency, Tennessee Valley Authority, and the States of Minnesota, Wisconsin, Iowa, Illinois, Missouri, Kansas, and Nebraska. For the Missouri River basin, this study reviewed, updated, and revised, as appropriate, the existing hydrology for the Missouri River from Yankton, South Dakota to the mouth of the Missouri River. The existing hydrology for the Missouri River was last updated in 1962, so a substantial additional period of hydrologic record was available for analysis. A hydraulic analysis using unsteady flow numerical modeling was utilized to develop water surface profiles for the Missouri River throughout the study reach. Changes were noted over time because of changes in hydrology as well as in the Missouri River itself primarily from aggradation and degradation. In the future, this study will need to be updated to reflect changed conditions and additional hydrologic data.

Appendix I – Adaptive Management

I-01. **Introduction.** This appendix presents and discusses the areas related to the historic and proposed adaptive management of the System. The Corps has been functioning in an adaptive management mode for many years; however, this water control plan provides for a formalization of this process. This process is discussed in Chapter 7.

I-02. **Previous Proposed Actions.** As discussed previously, adaptive management had been incorporated into the regulation of the System prior to the update of this Master Manual. There is a long history of the Corps working with various State and Federal wildlife and fisheries interests to provide significant fish and wildlife enhancement in and downstream of the System. The following is a discussion of recent adaptive management actions that are currently included in System regulation considerations. These actions are intended to be implemented when hydrologic conditions allow.

I-02.1. **Reservoir Unbalancing.** System unbalancing has been implemented for many years to accomplish the authorized System project purpose of fish and wildlife. The use of storage in one or more reservoirs to enhance fish spawning and habitat creation is as old as when the System first filled. Early attempts to provide rising pools for northern pike and other game fish spawning were requested as the reservoirs reached the top of their Carryover Multiple Use Zones. The Corps has tried to implement these requests whenever it was possible to do so. Reservoir unbalancing has matured over time into the formal process shown in the Table I -1. The modified operation involves unbalancing the three large upper reservoirs to benefit reservoir fishery and the three threatened and endangered (T&E) species. The unbalancing would alternate at each project; high one year, float (normal operation) the next year, and low the third year. Table I-2 shows the reservoir elevations proposed by the MRNRC at which the unbalancing would be terminated. The ability to provide steady to rising pool levels at all of the System reservoirs during low water years is very dependent on the volume, timing, and distribution of runoff. Therefore, one or more reservoirs may be selected each year for emphasis in the enhancement of fishery resource management to the extent reasonably possible.

I-02.2. **Fort Peck T&E Species Tests.** These tests involve the use of a combination of spillway and powerplant releases to evaluate and test the ability of the Fort Peck project to provide warmer and significantly higher flows for T&E species and native river fishery enhancement.

I-02.2.1. **Fort Peck Mini-Test.** The first of these two modified regulation tests is a release modification for the endangered pallid sturgeon. When Fort Peck Lake has adequate water above the spillway crest by mid- to late May of any year, a T&E species release modification mini-test will be conducted in early June to monitor the effects of higher spring and warmer releases from the spillway. The purposes of the mini-test are to allow for an evaluation of the integrity of the spillway structure, to test data collection methodology, and to gather information on river temperatures with various combinations of flow from the spillway and powerhouse. Stream-bank erosion and fishing impacts will also be monitored. Stop protocol for the mini-test are identified in the Fort Peck Flow Modification Mini-Test Environmental Assessment, dated March 2004. Before either test is run, the Corps will fully coordinate with the Tribes of the Fort Peck Reservation, the State of Montana, and any other potentially affected stakeholders.

Table I-1
Reservoir Unbalancing Schedule

	Fort Peck		**Garrison**		**Oahe**	
Year	**March 1**	**Rest of Year**	**March 1**	**Rest of Year**	**March 1**	**Rest of year**
1	High	Float	Low	Hold Peak	Raise & hold during spawn	Float
2	Raise & hold during spawn	Float	High	Float	Low	Hold peak
3	Low	Hold peak	Raise & hold during spawn	Float	High	Float

Notes:
Float year: Normal operation, then unbalance 1 foot during low pool years or 3 feet when System storage is near 57.1 MAF on March 1.
Low year: Begin low, then hold peak the remainder of the year.
High year: Begin high, raise and hold pool during spawn, then float.

Table I-2

Reservoir Elevation Guidelines for Unbalancing (MRNRC)

	Fort Peck	**Garrison**	**Oahe**
Implement unbalancing if March 1 reservoir elevation is above this level.	2234 feet msl	1837.5 feet msl	1607.5 feet msl
Implement unbalancing if March 1 reservoir elevation is in this range and the pool is expected to raise more than 3 feet after March 1.	2227-2234 feet msl	1827-1837.5 feet msl	1600-1607.5 feet msl
Scheduling Criteria	Avoid lake level decline during spawn period which ranges from April 15 to May 30	Schedule after spawn period of April 20 to May 20	Schedule after spawn period of April 8 to May 15

I-02.2.1.1. During the Fort Peck mini-test, which will last about 4 weeks, flows will vary from 8,000 to 15,000 cfs as various combinations of spillway and powerplant releases are monitored. The maximum spillway release of 11,000 cfs will combine with a minimum powerplant release of 4,000 cfs for 6 days. This operation will be timed to avoid lowering the reservoir during the forage fish spawn. The mini-test will not be conducted if sufficient flows will not pass over the spillway crest (elevation 2225 feet msl). A minimum reservoir elevation of about 2229 feet msl is needed during the test to avoid unstable flows over the spillway.

I-02.2.2. **Fort Peck Full Test.** A more extensive test, referred to as the "full test," with a combined 20,000 to 25,000 cfs release from Fort Peck Dam is scheduled to be conducted beginning in early June in the year following the mini-test. This test would allow further tests of the integrity of the spillway and to determine if warm water releases will benefit the native river fishery. Peak outflows during the full test would be maintained for 2 weeks within the 4-week test period.

I-02.3. **Modified System Regulation for Threatened and Endangered Species.** Releases from all projects except Oahe and Big Bend have been modified to accommodate endangered interior least tern and threatened piping plover nesting since 1986. Daily hydropower peaking patterns are developed prior to nest initiation in early to mid-May and are provided to Western. Fort Peck and Garrison peaking has been limited in the past to 4 of 5 units for no more than 6 hours each day. Fort Randall peaking has been limited in the past to 7 of 8 units for no more than 6 hours per day.

I-02.3.1. **Gavins Point Cycling.** During the early years of System regulation for endangered species, a technique of increasing project releases every third day by 8,000 to 10,000 cfs was used to encourage terns and plovers to build their nests on higher habitat so that these nests would not be inundated later when increases were required to meet the regulation objectives of the System. This pattern of increasing releases every third day was referred to as "cycling." Cycling has not been used in recent years because of the potential harm to native fish and the risk of stranding chicks. Every third day "cycling" of Gavins Point Dam releases during release reductions for downstream flood control has been used to keep birds nesting at sufficiently high elevations to maintain room for release increases when downstream flooding has subsided. The variation in releases is normally limited to 8,000 cfs to minimize adverse affects on downstream river users and fish.

I-02.3.2. **Gavins Point Steady Release.** Another technique, called "steady release," has been used and involves increasing the Gavins Point Dam release by early to mid-May when the terns and plovers begin to initiate nesting activities to the amount expected to be needed for downstream flow support in August when downstream tributary flows are typically lower. This uses an additional amount of water stored in the System but usually preserves the ability to support downstream flow objectives and meet endangered species objectives as well. This type of release from Gavins Point Dam has been successfully used many times since System regulation for threatened and endangered species nesting began.

I-02.3.3. **Gavins Point Flow-to-Target Release.** Prior to the System regulating for endangered species, a "flow-to-target" approach was implemented where releases from the System were increased as needed to provide downstream flow support. While this approach preserved the most habitat during the initial nesting phase, it normally resulted in the inundation of nests as downstream tributary flows fell off and Gavins Point Dam releases were increased to meet downstream target flows.

I-02.3.4. **Gavins Point Steady Release – Flow to Target.** During the 2003 nesting season, a new procedure, called "steady release – flow to target" was used to set the Gavins Point Dam release. This procedure combined features of the original "flow-to-target" method with the "steady release" plan. It called for an initial steady release high enough to inundate low-lying habitat that would likely be subject to inundation later in the season. As downstream tributary flows declined through the summer, releases could be increased as needed, within the limits of the Incidental Take Statement provided by the Service in its Supplemental BiOp prepared for the 2003 AOP, to meet downstream flow support for navigation and other authorized purposes.

I-03. **New Proposed Actions**. There are several actions that have been discussed and will be considered in future adaptive management implementations. There are numerous proposals for the adjustment of river flows to enhance native river fish in all reaches of the Missouri River. There have also been discussions of short-term higher releases to condition T&P habitat.

I-03.1. **U.S. Fish and Wildlife Service 2000 Biological Opinion.** The Corps entered into formal consultation with the U.S. Fish and Wildlife Service (Service) that culminated in the Service's Missouri River Biological Opinion (BiOp) issued in November 2000 (2000 BiOp). The 2000 BiOp concluded the Corps' proposed action jeopardized the continued existence of the listed pallid sturgeon, piping plover, and the interior least tern, and recommended a Reasonable and Prudent Alternative (RPA) to avoid jeopardy.

I-03.1.1. In November 3, 2003, the Corps requested reinitiation of formal ESA consultation. The request for reinitiation was based on the existence of new information regarding effects of the System regulation on the Federally listed species as well as a new critical habitat designation for one of the listed species. The Corps' description of this information and of the proposed action was set forth in a detailed biological assessment accompanying the request to reinitiate consultation. There were several possible actions presented in the Corp's biological assessment that will not be restated here.

I-03.2. **Service's 2003 Amended BiOp**. On December 16, 2003, in response to the Corps' request for the reinitiation of consultation, the Service issued an amendment to its 2000 BiOp. The 2003 Amended BioOp includes an RPA for the Corps' proposed operations that the Service believes, if implemented, would avoid the likelihood of jeopardizing the continued existence of the endangered pallid sturgeon or result in the destruction or adverse modification of its critical habitat. The RPA flow components for pallid sturgeon replaced the Corps' proposed three-year re-evaluation with a "feasibility, flow development, and adaptive management" element to determine how flows can be provided that are essential for the survival of the pallid sturgeon by March 2006. The evaluation of a "spring rise" described in the 2003 Amended BiOp will include a review of the status of the species, the scientific findings of a research, monitoring, and evaluation program, the progress and success of measures implemented to date, and other relevant new information. Decisions concerning implementation of additional measures or modification of existing measures, including potential release changes out of Gavins Point Dam, will be made through the adaptive management process. The two-year re-evaluation will include input from Missouri River stakeholders to foster conservation of ESA-listed species and the broader ecosystem values of the Missouri River while providing other Congressionally authorized System project purposes. This process has been incorporated into the Selected Plan.

I-03.2.1. Another RPA element states that when 1,200 acres of new shallow water habitat for pallid sturgeon have been made available, the Corps, in consultation with the USFWS, may modify the summer flows to take advantage of that habitat and more fully meet the Congressionally authorized System project purposes. In letters to the USFWS dated February 13, 2004 and March 2, 2004, the Corps identified a plan and biological rationale to support development of shallow water habitat in an expanded reach from Ponca State Park to the Osage River by July 1, 2004. By letter dated March 5, 2004, the USFWS concurred that there is sufficient biological information to support the expanded reach and also supported the Corps' decision to develop 1,200 new acres of shallow water habitat as a means to address an immediate need for survival and recovery of the pallid sturgeon. The Corps and USFWS will consult in early June 2004 to take into account the newly developed shallow water habitat in association with a request for flow modification to provide for all project purposes including service to navigation throughout the summer of 2004. The Selected Plan reflects this agreed upon approach to implement this element of the RPA.

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Summary of Engineering Data -- Missouri River Mainstem System

Item No.	Subject	Fort Peck Lake	Garrison Dam - Lake Sakakawea	Oahe Dam - Lake Oahe
1	Location of Dam	Near Glasgow, Montana	Near Garrison, ND	Near Pierre, SD
2	River Mile - 1960 Mileage	Mile 1771.5	Mile 1389.9	Mile 1072.3
3	Total & incremental drainage areas in square miles	57,500	181,400 (2) 123,900	243,490 (1) 62,090
4	Approximate length of full reservoir (in valley miles)	134, ending near Zortman, MT	178, ending near Trenton, ND	231, ending near Bismarck, ND
5	Shoreline in miles (3)	1520 (elevation 2234)	1340 (elevation 1837.5)	2250 (elevation 1607.5)
6	Average total & incremental inflow in cfs	10,200	25,600 15,400	28,900 3,300
7	Max. discharge of record near damsite in cfs	137,000 (June 1953)	348,000 (April 1952)	440,000 (April 1952)
8	Construction started - calendar yr.	1933	1946	1948
9	In operation (4) calendar yr.	1940	1955	1962
	<u>Dam and Embankment</u>			
10	Top of dam, elevation in feet msl	2280.5	1875	1660
11	Length of dam in feet	21,026 (excluding spillway)	11,300 (excluding spillway)	9,300 (excluding spillway)
12	Damming height in feet (5)	220	180	200
13	Maximum height in feet (5)	250.5	210	245
14	Max. base width, total & w/o berms in feet	3500, 2700	3400, 2050	3500, 1500
15	Abutment formations (under dam & embankment)	Bearpaw shale and glacial fill	Fort Union clay shale	Pierre shale
16	Type of fill	Hydraulic & rolled earth fill	Rolled earth filled	Rolled earth fill & shale berms
17	Fill quantity, cubic yards	125,628,000	66,500,000	55,000,000 & 37,000,000
18	Volume of concrete, cubic yards	1,200,000	1,500,000	1,045,000
19	Date of closure	24 June 1937	15 April 1953	3 August 1958
	<u>Spillway Data</u>			
20	Location	Right bank - remote	Left bank - adjacent	Right bank - remote
21	Crest elevation in feet msl	2225	1825	1596.5
22	Width (including piers) in feet	820 gated	1336 gated	456 gated
23	No., size and type of gates	16 - 40' x 25' vertical lift gates	28 - 40' x 29' Tainter	8 - 50' x 23.5' Tainter
24	Design discharge capacity, cfs	275,000 at elev 2253.3	827,000 at elev 1858.5	304,000 at elev 1644.4
25	Discharge capacity at maximum operating pool in cfs	230,000	660,000	80,000
	<u>Reservoir Data (6)</u>			
26	Max. operating pool elev. & area	2250 msl 246,000 acres	1854 msl 380,000 acres	1620 msl 374,000 acres
27	Max. normal op. pool elev. & area	2246 msl 240,000 acres	1850 msl 364,000 acres	1617 msl 360,000 acres
28	Base flood control elev & area	2234 msl 212,000 acres	1837.5 msl 307,000 acres	1607.5 msl 312,000 acres
29	Min. operating pool elev. & area	2160 msl 90,000 acres	1775 msl 128,000 acres	1540 msl 117,000 acres
	<u>Storage allocation & capacity</u>			
30	Exclusive flood control	2250-2246 975,000 a.f.	1854-1850 1,489,000 a.f.	1620-1617 1,102,000 a.f.
31	Flood control & multiple use	2246-2234 2,717,000 a.f.	1850-1837.5 4,222,000 a.f.	1617-1607.5 3,201,000 a.f.
32	Carryover multiple use	2234-2160 10,785,000 a.f.	1837.5-1775 13,130,000 a.f.	1607.5-1540 13,461,000 a.f.
33	Permanent	2160-2030 4,211,000 a.f.	1775-1673 4,980,000 a.f.	1540-1415 5,373,000 a.f.
34	Gross	2250-2030 18,688,000 a.f.	1854-1673 23,821,000 a.f.	1620-1415 23,137,000 a.f.
35	Reservoir filling initiated	November 1937	December 1953	August 1958
36	Initially reached min. operating pool	27 May 1942	7 August 1955	3 April 1962
37	Estimated annual sediment inflow	18,100 a.f. 1030 yrs.	25,900 a.f. 920 yrs.	19,800 a.f. 1170 yrs.
	<u>Outlet Works Data</u>			
38	Location	Right bank	Right Bank	Right Bank
39	Number and size of conduits	2 - 24' 8" diameter (nos. 3 & 4)	1 - 26' dia. and 2 - 22' dia.	6 - 19.75' dia. upstream, 18.25' dia. downstream
40	Length of conduits in feet (8)	No. 3 - 6,615, No. 4 - 7,240	1529	3496 to 3659
41	No., size, and type of service gates	1 - 28' dia. cylindrical gate 6 ports, 7.6' x 8.5' high (net opening) in each control shaft	1 - 18' x 24.5' Tainter gate per conduit for fine regulation	1 - 13' x 22' per conduit, vertical lift, 4 cable suspension and 2 hydraulic suspension (fine regulation)
42	Entrance invert elevation (msl)	2095	1672	1425
43	Avg. discharge capacity per conduit & total	Elev. 2250 22,500 cfs - 45,000 cfs	Elev. 1854 30,400 cfs - 98,000 cfs	Elev. 1620 18,500 cfs - 111,000 cfs
44	Present tailwater elevation (ft msl)	2032-2036 5,000 - 35,000 cfs	1670-1680 15,000- 60,000 cfs	1423-1428 20,000-55,000 cfs
	<u>Power Facilities and Data</u>			
45	Avg. gross head available in feet (14)	194	161	174
46	Number and size of conduits	No. 1-24'8" dia., No. 2-22'4" dia.	5 - 29' dia., 25' penstocks	7 - 24' dia., imbedded penstocks
47	Length of conduits in feet (8)	No. 1 - 5,653, No. 2 - 6,355	1829	From 3,280 to 4,005
48	Surge tanks	PH#1: 3-40' dia., PH#2: 2-65' dia.	65' dia. - 2 per penstock	70' dia., 2 per penstock
49	No., type and speed of turbines	5 Francis, PH#1-2: 128.5 rpm, 1-164 rpm , PH#2-2: 128.6 rpm	5 Francis, 90 rpm	7 Francis, 100 rpm
50	Discharge cap. at rated head in cfs	PH#1, units 1&3 170', 2-140' 8,800 cfs, PH#2-4&5 170'-7,200 cfs	150' 41,000 cfs	185' 54,000 cfs
51	Generator nameplate rating in kW	1&3: 43,500; 2: 18,250; 4&5: 40,000	3 - 109,250, 2 - 95,000	112,290
52	Plant capacity in kW	185,250	517,750	786,030
53	Dependable capacity in kW (9)	181,000	388,000	534,000
54	Avg. annual energy, million kWh (12)	1,142	2,429	2,867
55	Initial generation, first and last unit	July 1943 - June 1961	January 1956 - October 1960	April 1962 - June 1963
56	Estimated cost September 1999 completed project (13)	$158,428,000	$305,274,000	$346,521,000

MISSOURI RIVER BASIN
Summary of Engineering Data

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-1

Summary of Engineering Data -- Missouri River Mainstem System

Big Bend Dam - Lake Sharpe	Fort Randall Dam - Lake Francis Case	Gavins Point Dam - Lewis & Clark Lake	Total	Item No.
21 miles upstream Chamberlain, SD	Near Lake Andes, SD	Near Yankton, SD		1
Mile 987.4	Mile 880.0	Mile 811.1		2
249,330 (1) 5,840	263,480 (1) 14,150	279,480 (1) 16,000		3
80, ending near Pierre, SD	107, ending at Big Bend Dam	25, ending near Niobrara, NE	755 miles	4
200 (elevation 1420)	540 (elevation 1350)	90 (elevation 1204.5)	5,940 miles	5
28,900	30,000 1,100	32,000 2,000		6
440,000 (April 1952)	447,000 (April 1952)	480,000 (April 1952)		7
1959	1946	1952		8
1964	1953	1955		9
1440	1395	1234		10
10,570 (including spillway)	10,700 (including spillway)	8,700 (including spillway)	71,596	11
78	140	45	863 feet	12
95	165	74		13
1200, 700	4300, 1250	850, 450		14
Pierre shale & Niobrara chalk	Niobrara chalk	Niobrara chalk & Carlile shale		15
Rolled earth, shale, chalk fill	Rolled earth fill & chalk berms	Rolled earth & chalk fill		16
17,000,000	28,000,000 & 22,000,000	7,000,000	358,128,000 cu. yds	17
540,000	961,000	308,000	5,554,000 cu. yds.	18
24 July 1963	20 July 1952	31 July 1955		19
Left bank - adjacent	Left bank - adjacent	Right bank - adjacent		20
1385	1346	1180		21
376 gated	1000 gated	664 gated		22
8 - 40' x 38' Tainter	21 - 40' x 29' Tainter	14 - 40' x 30' Tainter		23
390,000 at elev 1433.6	620,000 at elev 1379.3	584,000 at elev 1221.4		24
270,000	508,000	345,000		25
1423 msl 61,000 acres	1375 msl 102,000 acres	1210 msl 31,000 acres	1,194,000 acres	26
1422 msl 60,000 acres	1365 msl 95,000 acres	1208 msl 28,000 acres	1,147,000 acres	27
1420 msl 57,000 acres	1350 msl 77,000 acres	1204.5 msl 24,000 acres	989,000 acres	28
1415 msl 51,000 acres	1320 msl 38,000 acres	1204.5 msl 24,000 acres	450,000 acres	29
1423-1422 60,000 a.f.	1375-1365 985,000 a.f.	1210-1208 59,000 a.f.	4,670,000 a.f.	30
1422-1420 117,000 a.f.	1365-1350 1,309,000 a.f.	1208-1204.5 90,000 a.f.	11,656,000 a.f.	31
	1350-1320 1,607,000 a.f.		38,983,000 a.f.	32
1420-1345 1,682,000 a.f.	1320-1240 1,517,000 a.f.	1204.5-1160 321,000 a.f.	18,084,000 a.f.	33
1423-1345 1,859,000 a.f.	1375-1240 5,418,000 a.f.	1210-1160 470,000 a.f.	73,393,000 a.f.	34
November 1963	January 1953	August 1955		35
25 March 1964	24 November 1953	22 December 1955		36
4,300 a.f. 430 yrs.	18,300 a.f. 250 yrs.	2,600 a.f. 180 yrs.	92,500 a.f.	37
	Left Bank			38
None (7)	4 - 22' diameter	None (7)		39
	1013			40
	2 - 11' x 23' per conduit, vertical lift, cable suspension			41
1385 (11)	1229	1180 (11)		42
	Elev 1375 32,000 cfs - 128,000 cfs			43
1351-1355(10) 25,000-100,000 cfs	1228-1239 5,000-60,000 cfs	1155-1163 15,000-60,000 cfs		44
70	117	48	764 feet	45
None: direct intake	8 - 28' dia., 22' penstocks	None: direct intake		46
	1,074		55,083	47
None	59' dia, 2 per alternate penstock	None		48
8 Fixed blade, 81.8 rpm	8 Francis, 85.7 rpm	3 Kaplan, 75 rpm	36 units	49
67' 103,000 cfs	112' 44,500 cfs	48' 36,000 cfs		50
3 - 67,276, 5 - 58,500	40,000	44,100		51
494,320	320,000	132,300	2,435,650 kw	52
497,000	293,000	74,000	1,967,000 kw	53
1,041	1,843	754	10,077 million kWh	54
October 1964 - July 1966	March 1954 - January 1956	September 1956 - January 1957	July 1943 - July 1966	55
$107,498,000	$199,066,000	$49,617,000	$1,166,404,000	56

Remarks

(1) Includes 4,280 square miles of non-contributing areas.
(2) Includes 1,350 square miles of non-contributing areas.
(3) With pool at base of flood control.
(4) Storage first available for regulation of flows.
(5) Damming height is height from low water to maximum operating pool. Maximum height is from average streambed to top of dam.
(6) Based on latest available storage data.
(7) River regulation is attained by flows over low-crested spillway and through turbines.
(8) Length from upstream face of outlet or to spiral case.
(9) Based on 8th year (1961) of drought drawdown (From study 8-83-1985).
(10) Affected by level of Lake Francis case. Applicable to pool at elevation 1350.
(11) Spillway crest.
(12) 1967-2001 Average
(13) Source: Annual Report on Civil Works Activities of the Corps of Engineers. Extract Report Fiscal Year 1999.
(14) Based on Study 8-83-1985

Corps of Engineers, U.S. Army
Compiled by
Northwestern Division
Missouri River Region
May 2001

MISSOURI RIVER BASIN
Summary of Engineering Data

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-2

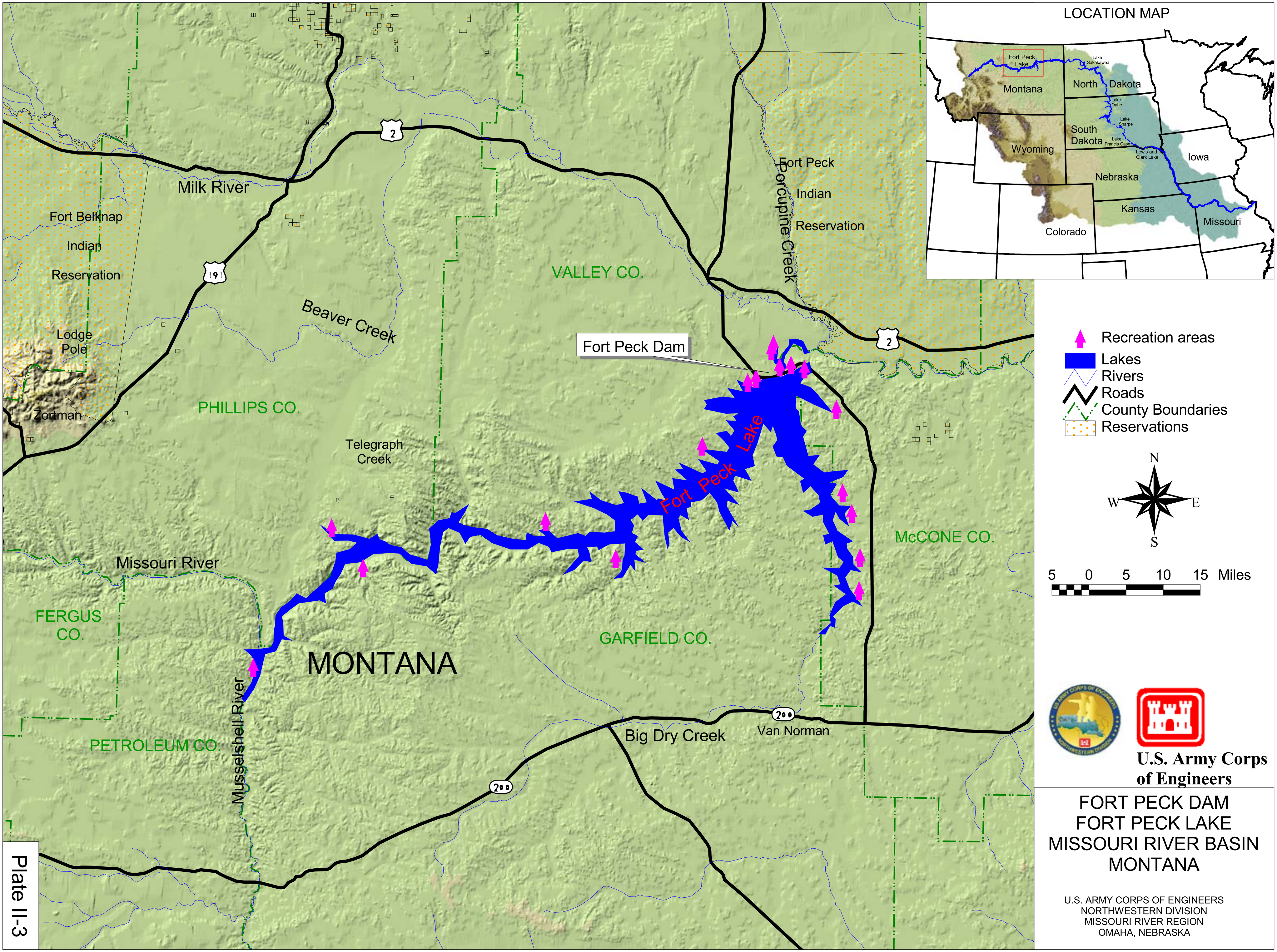
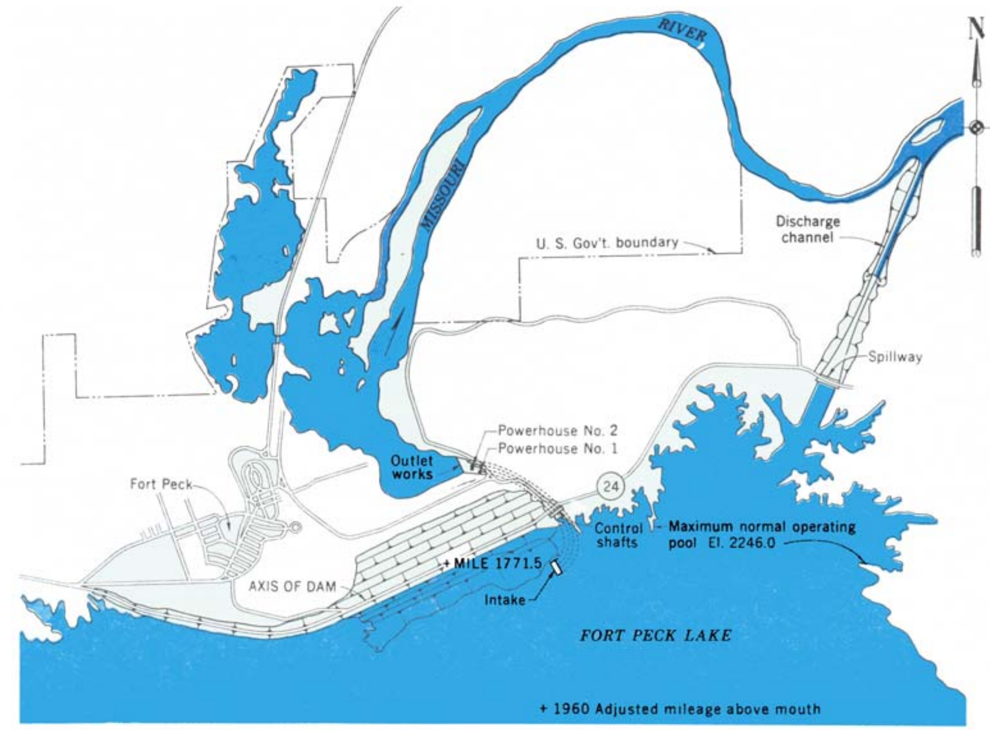
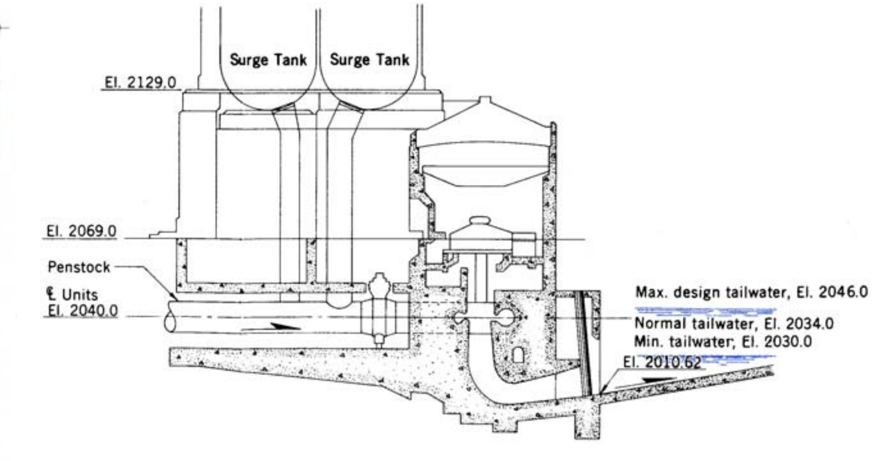

LOCATION MAP
Fort Peck Lake
Montana
North Dakota
Lake Sakakawea
Lake Oahe
Lake Sharpe
South Dakota
Lake Francis Case
Lewis and Clark Lake
Wyoming
Nebraska
Iowa
Kansas
Missouri
Colorado
Recreation areas
Lakes
Rivers
Roads
County Boundaries
Reservations
N
W
E
S
5 0 5 10 15 Miles
U.S. Army Corps of Engineers
FORT PECK DAM
FORT PECK LAKE
MISSOURI RIVER BASIN
MONTANA
U.S. ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
Milk River
Fort Belknap Indian Reservation
Lodge Pole
Zortman
PHILLIPS CO.
Beaver Creek
Telegraph Creek
VALLEY CO.
Fort Peck Indian Reservation
Porcupine Creek
Fort Peck Dam
Fort Peck Lake
McCONE CO.
Missouri River
FERGUS CO.
MONTANA
GARFIELD CO.
PETROLEUM CO.
Musselshell River
Big Dry Creek
Van Norman
2
191
200

Plate II-3

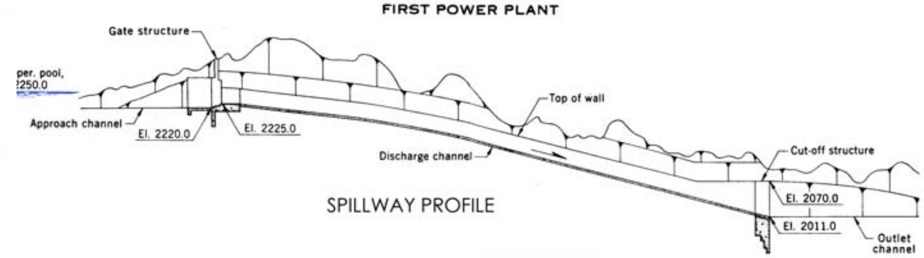


PLAN

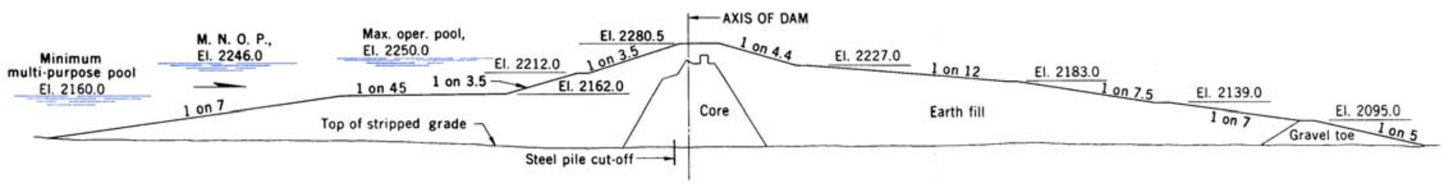


POWERHOUSE SECTION

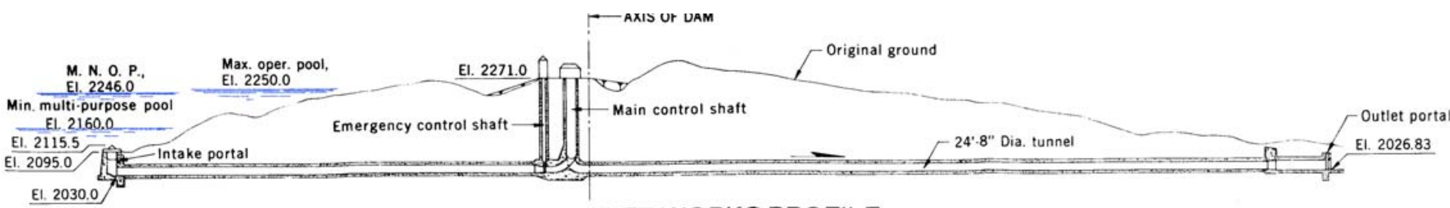
FIRST POWER PLANT



SPILLWAY PROFILE



MAXIMUM EMBANKMENT SECTION

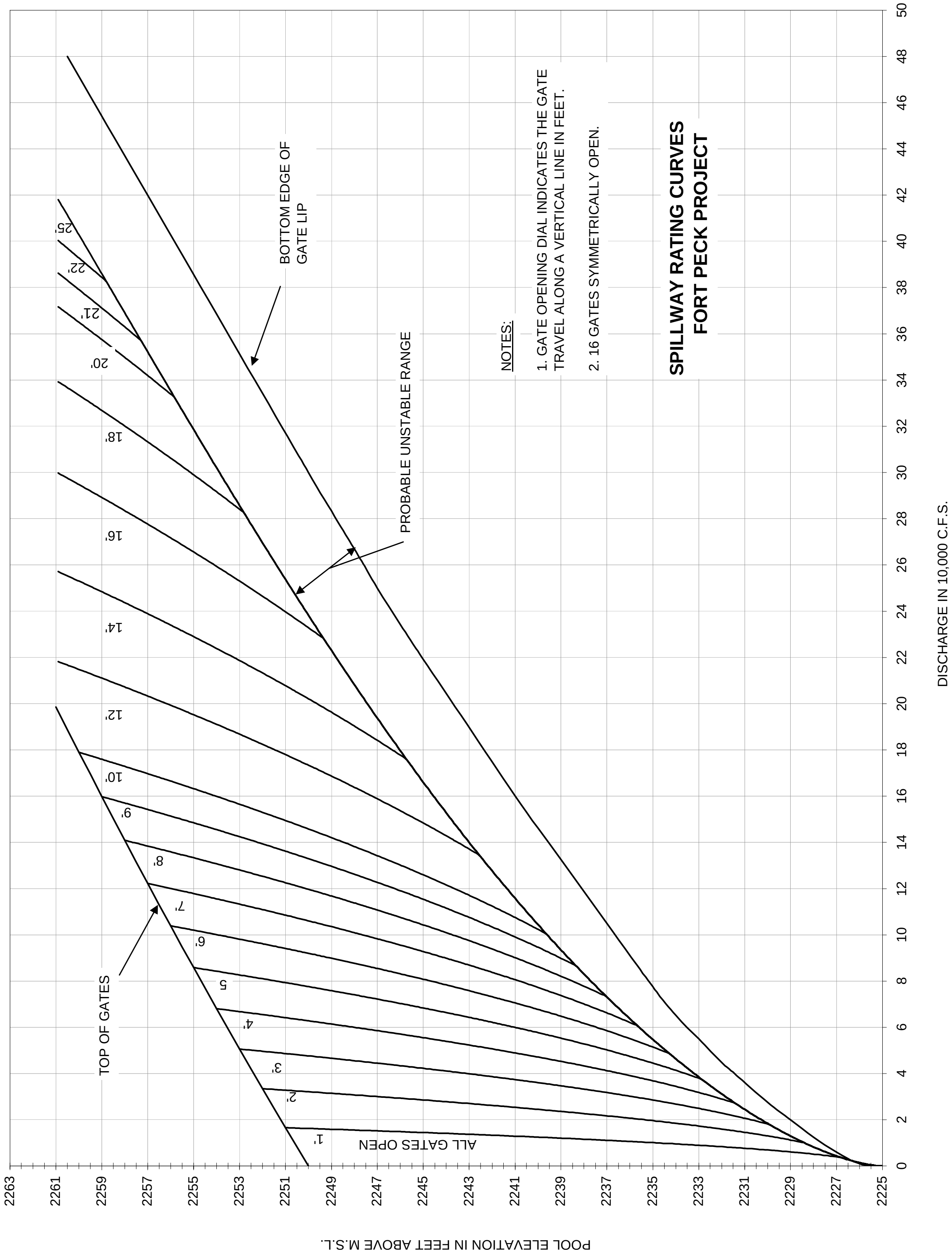


OUTLET WORKS PROFILE

Missouri River Basin
Fort Peck Dam
Fort Peck Lake
Flood Control Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

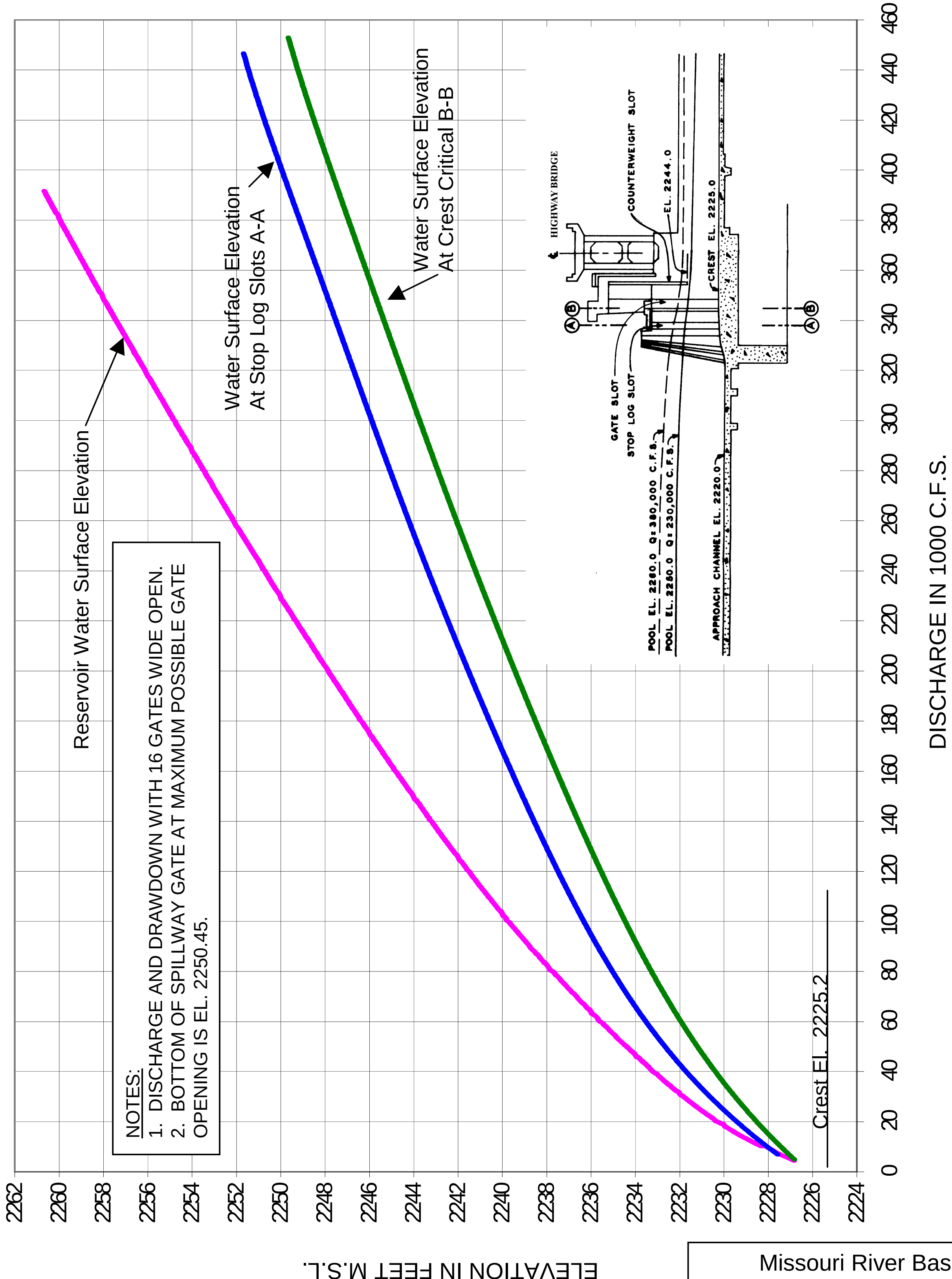
Plate II-4



Missouri River Basin
Spillway Rating Curves
Fort Peck Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-5

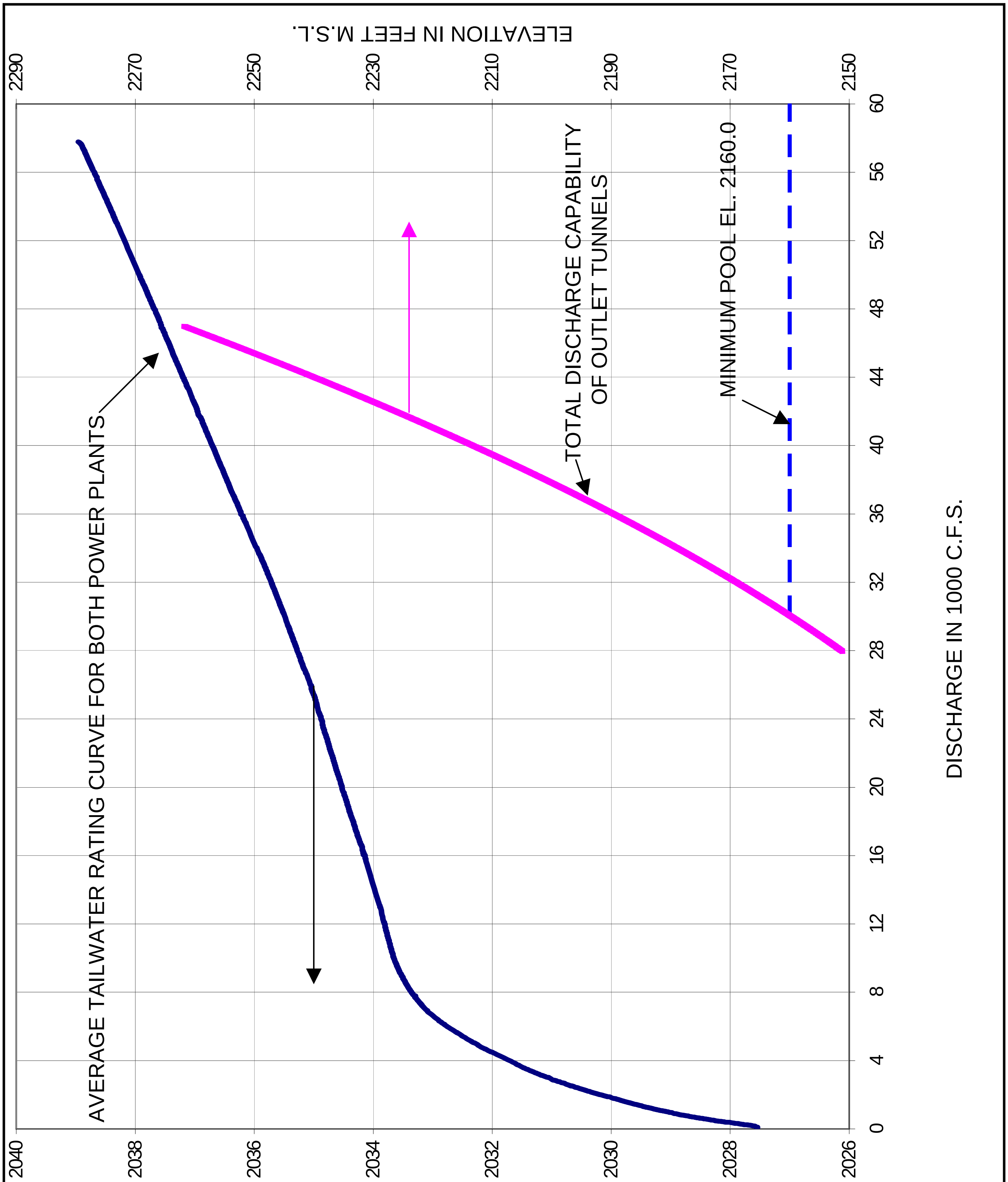


NOTES: 1. DISCHARGE AND DRAWDOWN WITH 16 GATES WIDE OPEN.
2. BOTTOM OF SPILLWAY GATE AT MAXIMUM POSSIBLE GATE OPENING IS EL. 2250.45

Missouri River Basin
Discharge Rating Curve and
Drawdown at Spillway Gates
Fort Peck Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

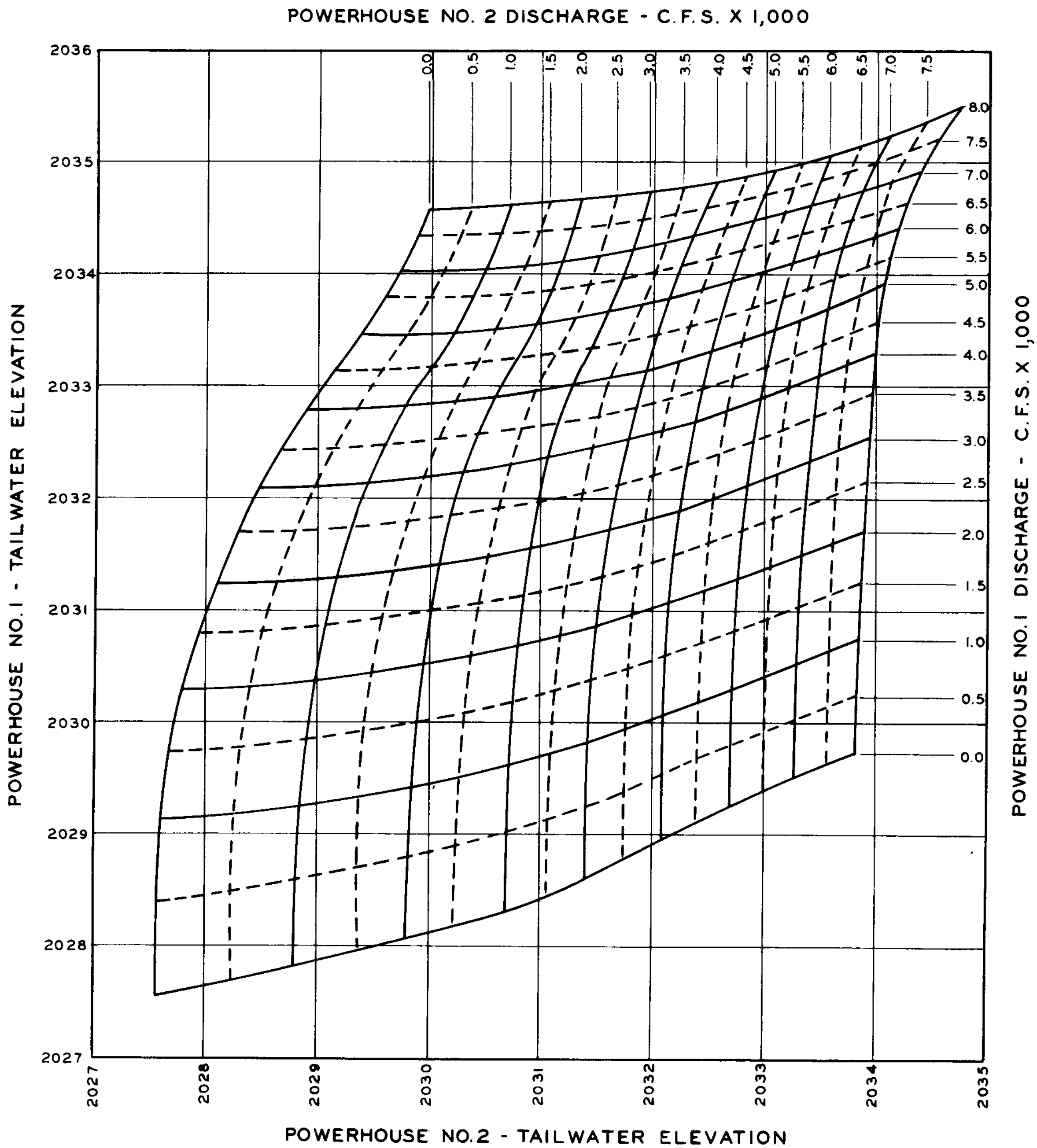
Plate II-6



Missouri River Basin
Powerplant, Tailwater Rating Curve and
Discharge Capability of Outlet Tunnels
Fort Peck Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-7



<u>DIRECTIONS</u>:

Tailwater elevation can be determined by following the Powerhouse No. 1 discharge curve to the left until the correct Powerhouse No. 2 discharge is reached. From this point read directly to the left for Powerhouse No. 1 tail-water elevations and straight down for Powerhouse No. 2 tailwater elevation.

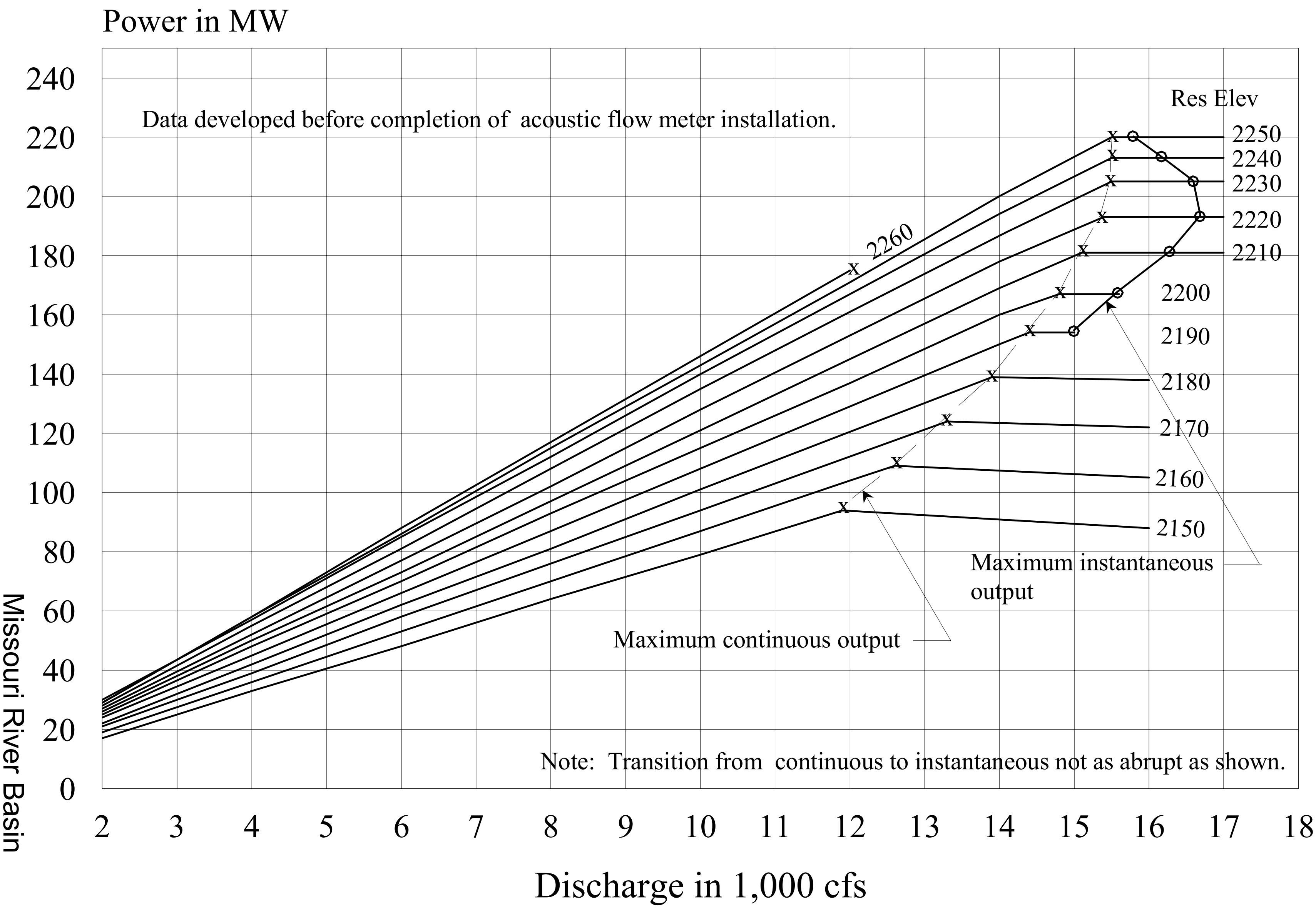
NOTES: These curves are only good when steady state flow conditions exist at both powerhouses.

Missouri River Basin
Fort Peck Project
Tailwater Rating Curves
Powerplant 1 and 2

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-8

Fort Peck Powerplant



Missouri River Basin
Fort Peck Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March2004
Plate II-9

Area in Acres
(1986 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
2030	0	0	0	0	70	107	98	116	180	289
2040	418	526	626	739	864	1004	1148	1275	1378	1456
2050	1480	1471	1532	1718	2030	2370	2636	2910	3284	3757
2060	4264	4720	5169	5669	6219	6753	7228	7749	8195	9167
2070	10043	10918	11683	12336	12861	13368	13961	14529	14962	15261
2080	15440	15612	15907	16360	16969	17618	16175	18739	19421	20221
2090	21086	21917	22700	23466	24716	24956	25700	26452	27208	27968
2100	28711	29433	30183	30889	31351	32736	33597	34447	35313	36197
2110	37047	37851	38710	39694	40801	41915	42933	43992	45214	46599
2120	48098	49577	50951	52224	53395	54523	55691	56883	58054	59204
2130	60371	61571	62739	63826	64834	65839	66907	67947	68877	69698
2140	70442	71199	72027	73923	73888	74856	75858	76811	77771	78738
2150	79683	80600	81553	82582	83687	84823	85926	87015	88126	89259
2160	90348	91374	92476	93745	95183	96624	97930	99299	100807	102759
2170	104794	106814	108657	110304	111757	113166	114693	116205	117556	118746
2180	119809	120879	122073	123405	124876	126382	127809	129240	130771	132402
2190	134099	135777	137400	135976	140505	142016	143545	145084	146614	148135
2200	149655	151181	152705	154219	135723	157232	158757	160268	161745	163188
2210	164592	165937	167425	168926	170489	172112	173742	175309	176791	178187
2220	179404	180513	181856	183608	185769	187984	189909	191927	194400	197331
2230	200565	203722	206614	209280	211721	214031	216398	213867	221389	223964
2240	226691	229527	232156	234406	236277	238094	240173	242175	243770	244958
2250	245898	246929	248163	249532	251037	252610	254137	255620	257102	258534
2260	260066									

Capacity in Acre-Feet
(1986 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
2030	0	0	0	0	26	140	240	336	473	696
2040	1052	1532	2105	2785	3584	4514	5593	6811	8144	9568
2050	11057	12528	13998	15592	17435	19652	22176	24924	27896	31492
2060	35511	40020	44952	50359	56290	62797	69796	77254	85295	94045
2070	103630	114131	125466	137510	150139	163232	176876	191155	205934	221079
2080	236456	251960	267680	283774	300400	317713	335636	354064	373115	392906
2090	413557	435078	457391	480478	504323	528910	554236	580811	607140	634727
2100	663076	692149	721943	752515	783921	816217	849393	883411	918287	954038
2110	990681	1028133	1066383	1105554	1145771	1187156	1229601	1273023	1317586	1363452
2120	1410784	1459649	1509939	1561552	1614387	1668343	1723433	1779726	1837200	1895834
2130	1955609	2016577	2078752	2142055	2206405	2271724	2338084	2405539	2473979	2543294
2140	2613376	2684178	2755774	2828232	2901620	2976009	3051393	3127726	3205016	3283269
2150	3362492	3442635	3523693	3505742	3688858	3773117	3858504	3944969	4032534	4121221
2160	4211053	4301918	4393801	4486870	4581292	4677236	4774541	4873096	4973140	5074914
2170	5478658	5284502	5392287	5501816	5612895	5725330	5839227	5954716	6071637	6189828
2180	6309129	6429447	6550883	6673593	6787699	6923345	7050464	7178964	7308944	7440506
2190	7573749	7708704	7845304	7983504	8123250	8264516	8407289	8551606	8697457	8844835
2200	8993728	9144145	9296090	9449555	9604529	9761001	9918994	10078516	10239531	10402006
2210	10565907	10731191	10887882	11066042	11235734	11407020	11579958	11754505	11930577	12108088
2220	12286952	12466897	12647979	12830609	13015195	13202148	13391163	13581967	13775017	13970768
2230	14169679	14371899	14577144	14785127	14995686	15208569	15423746	15641306	15861481	16084145
2240	1639409	16537527	16768464	17001540	17237276	17474394	17713464	17954740	18197814	18442280
2250	18687731	18934077	19151590	19430404	19680655	19932479	20185876	20440754	20697116	20854959
2260	21214285									

Missouri River Basin
Fort Peck Area-Capacity Tables

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-10

Missouri River Basin
Fort Peck Project
Embankment, Reservoir,
And Powerhouse

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-11

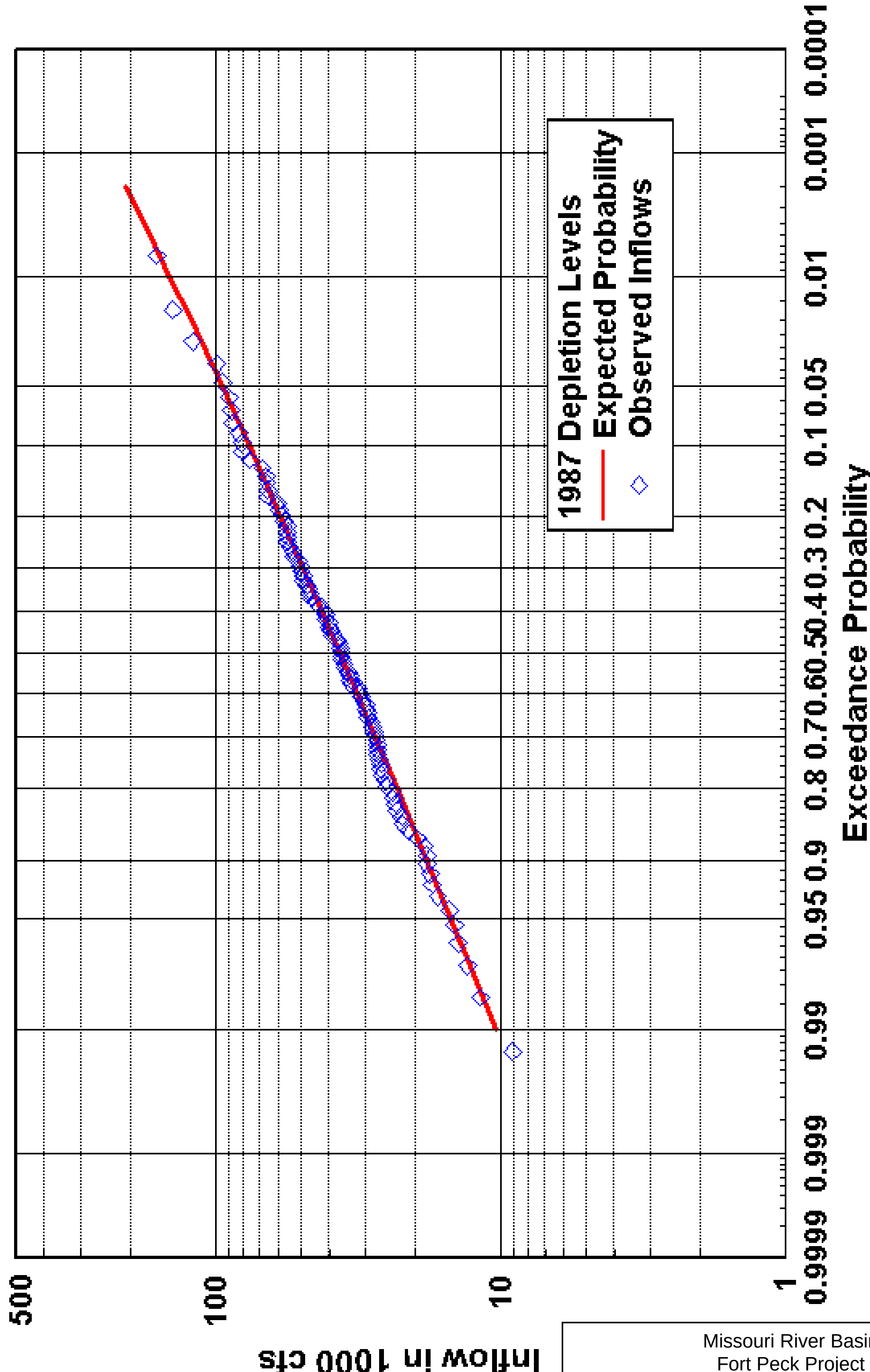
Powerhouse Structures

Spillway

Missouri River Basin
Fort Peck Project
Spillway and Powerhouse
Structures

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-12

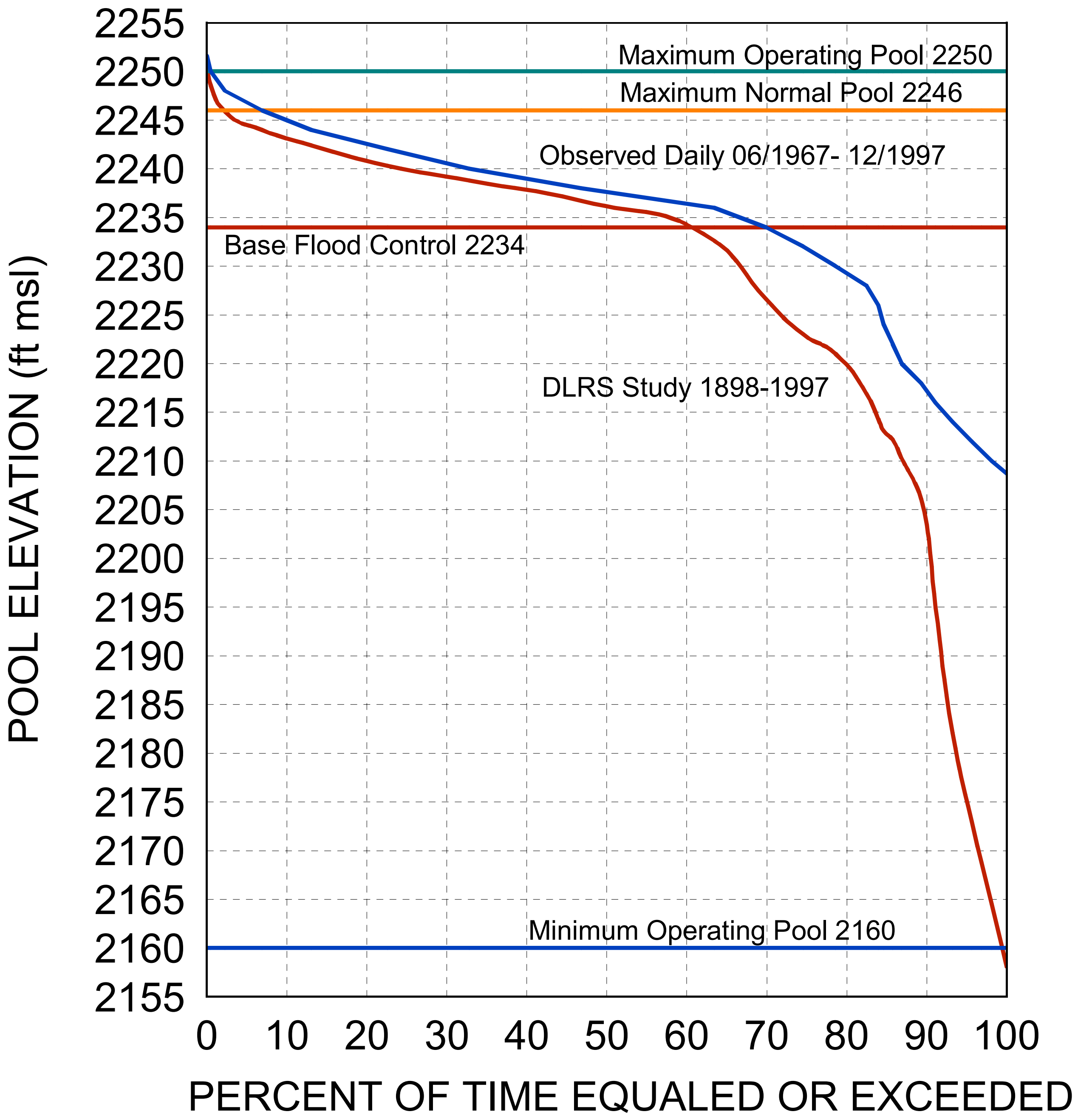


Missouri River Basin
Fort Peck Project
Inflow Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-13

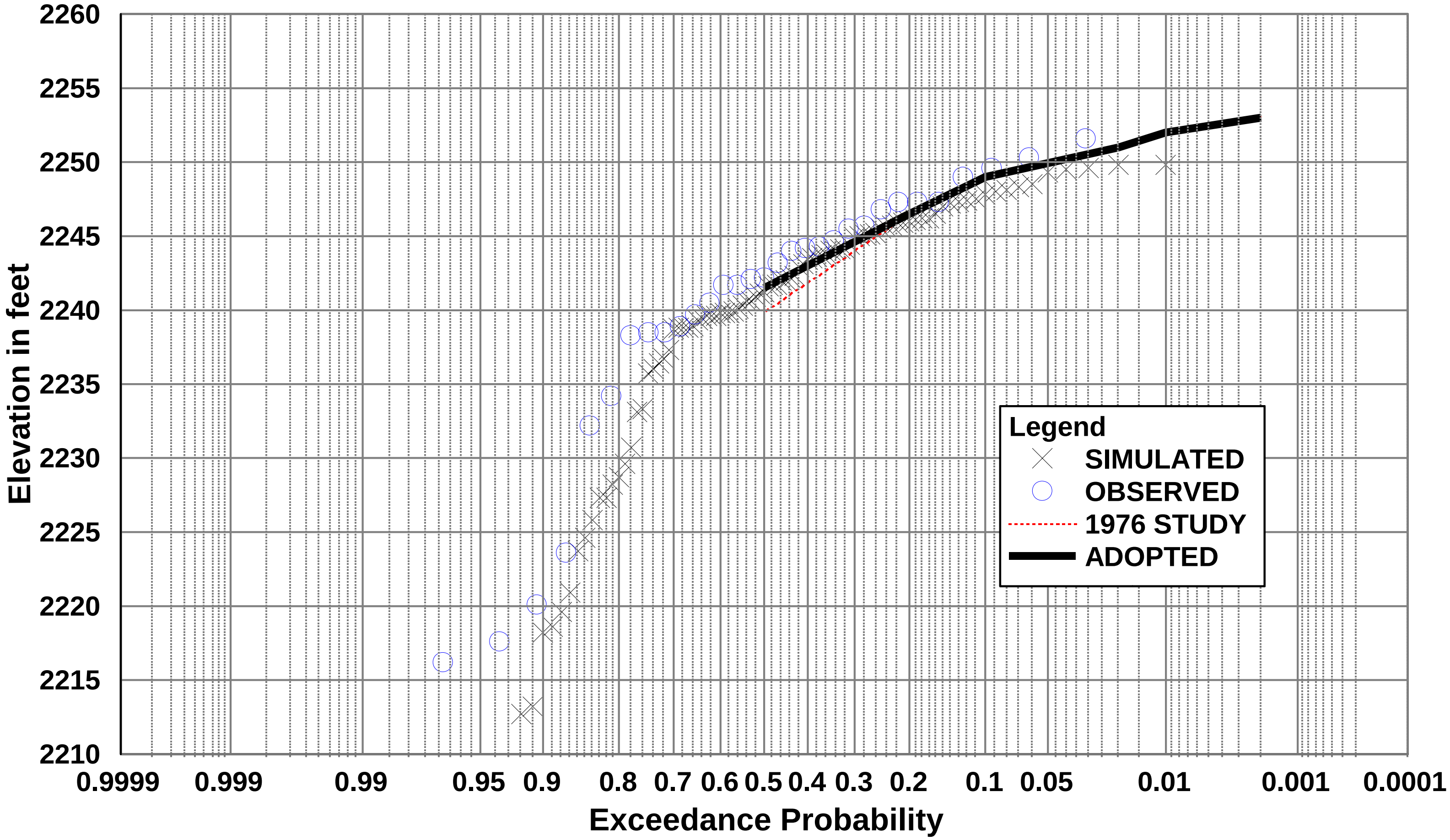
FORT PECK LAKE

POOL DURATION RELATIONSHIP



Missouri River Basin
Fort Peck Dam Pool Elevation Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

FORT PECK
POOL-PROBABILITY RELATIONSHIP



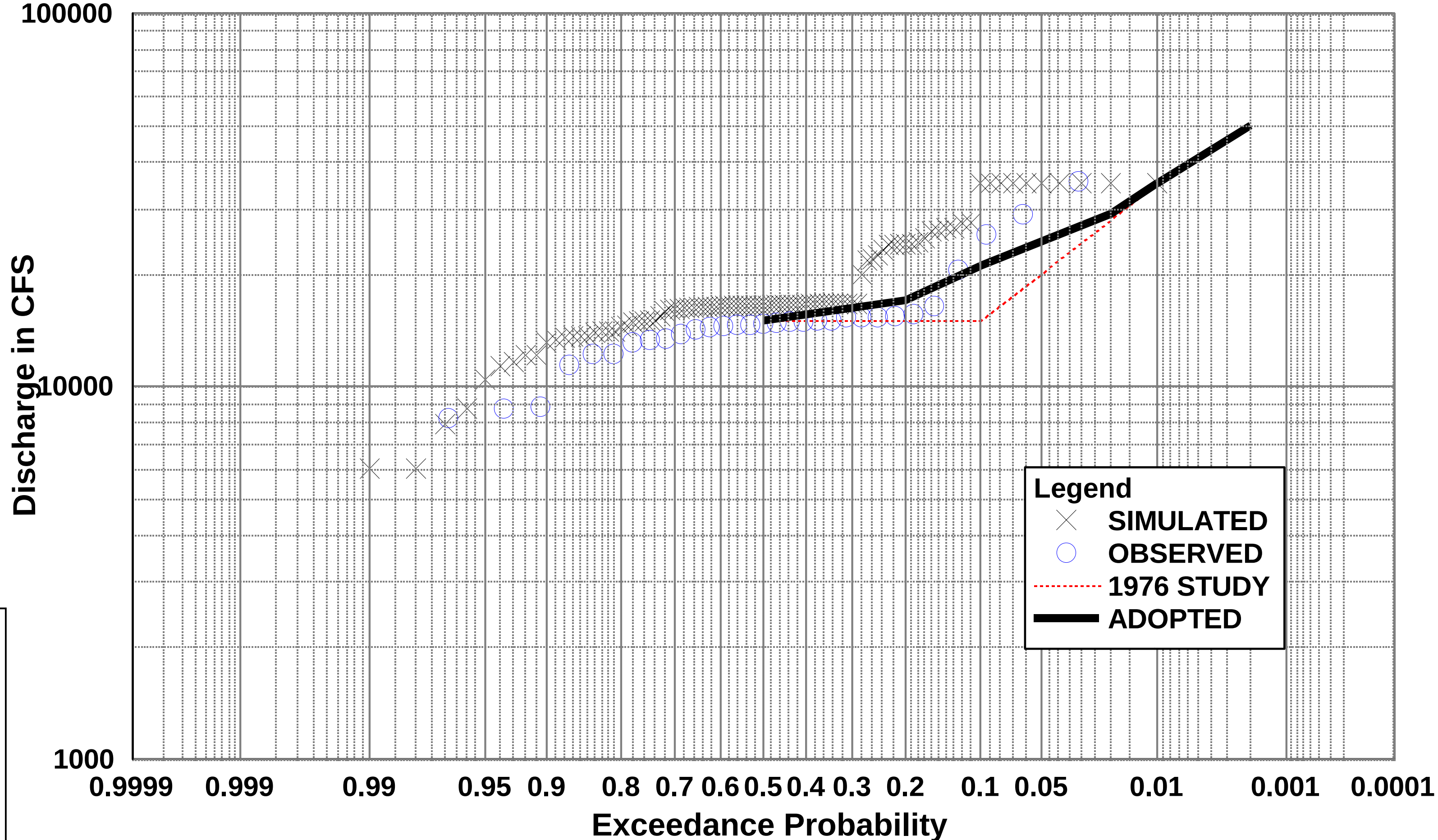
MAX POOL ELEVATION = 2256.1
MAX OP. POOL ELEV = 2250.0
MAX NORMAL POOL ELEV = 2246.0
BASE FLOOD CONTROL = 2234.0

Missouri River Basin
Fort Peck Project
Pool-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-15

FORT PECK
RELEASE-PROBABILITY RELATIONSHIP

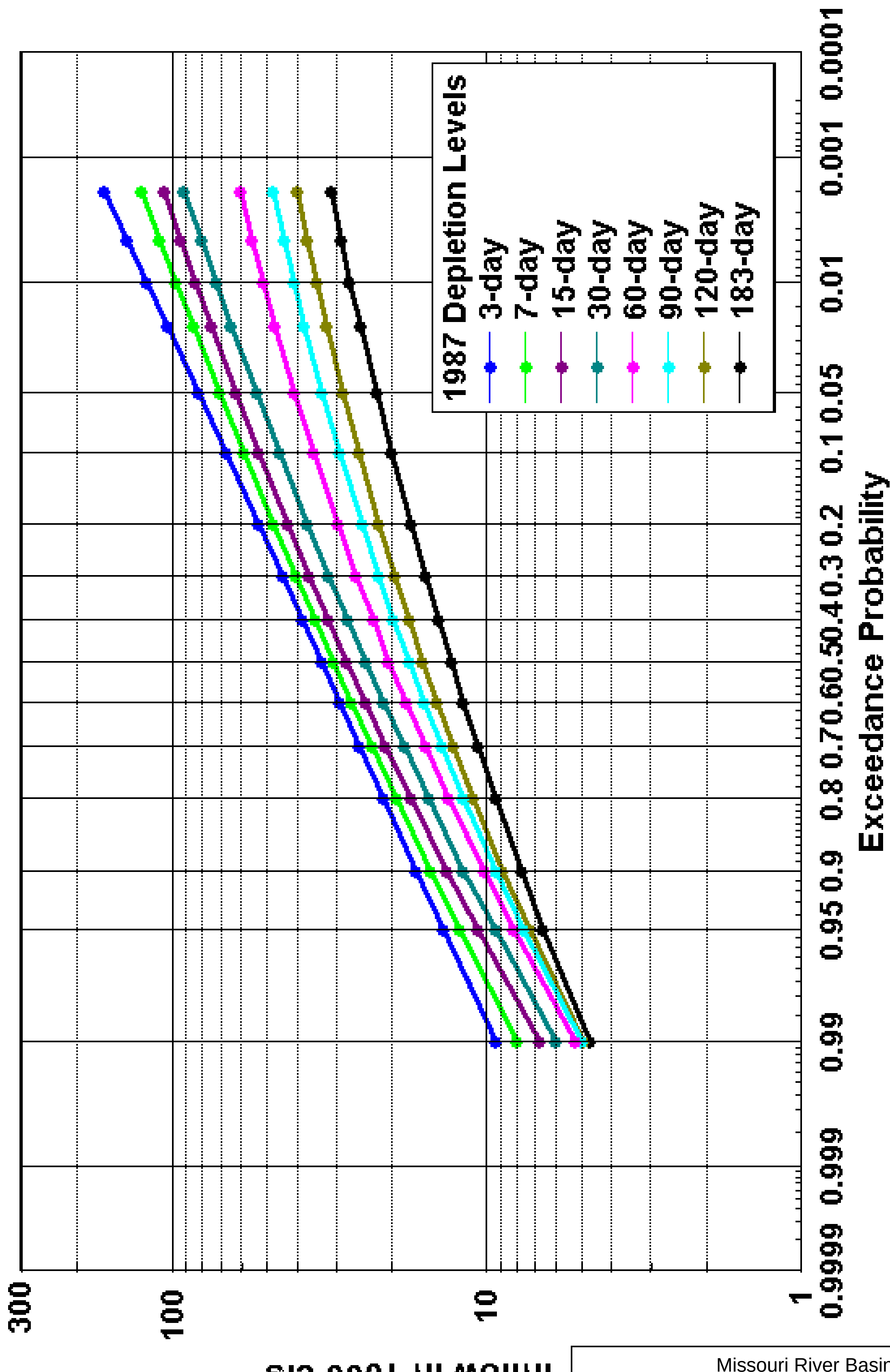


POWER PLANT CAPACITY = 16,000
OUTLET CAPACITY = 45,000
SPILLWAY CAPACITY = 275,000

Missouri River Basin
Fort Peck Project
Release-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-16



Missouri River Basin
Fort Peck Project
Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-17

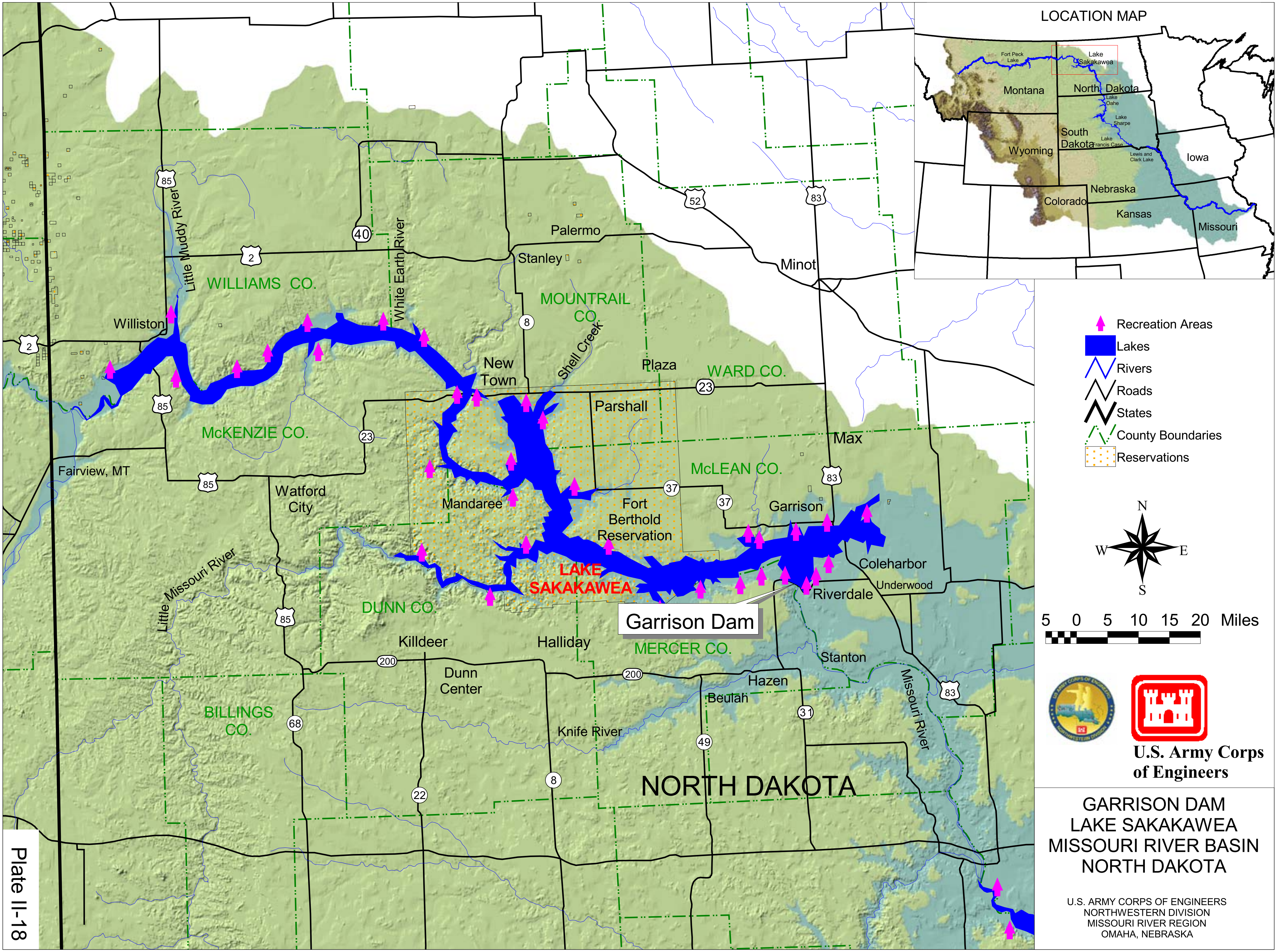
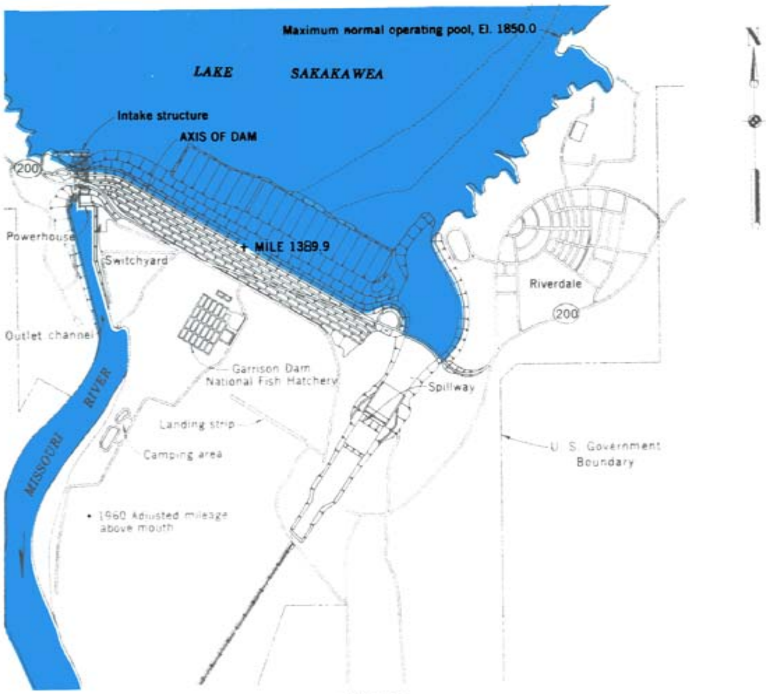
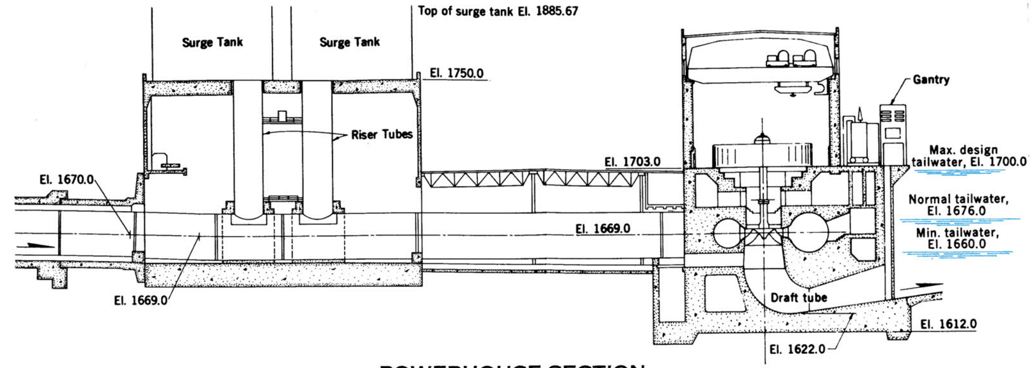

LOCATION MAP
Montana
North Dakota
South Dakota
Wyoming
Nebraska
Colorado
Kansas
Iowa
Missouri
Recreation Areas
Lakes
Rivers
Roads
States
County Boundaries
Reservations
N
S
E
W
5 0 5 10 15 20 Miles
U.S. Army Corps of Engineers
GARRISON DAM
LAKE SAKAKAWEA
MISSOURI RIVER BASIN
NORTH DAKOTA
U.S. ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA
Garrison Dam
LAKE SAKAKAWEA
NORTH DAKOTA
WILLIAMS CO.
McKENZIE CO.
MOUNTRAIL CO.
WARD CO.
McLEAN CO.
DUNN CO.
MERCER CO.
BILLINGS CO.
Williston
Fairview, MT
Watford City
New Town
Stanley
Palermo
Minot
Plaza
Parshall
Max
Garrison
Coleharbor
Underwood
Riverdale
Stanton
Hazen
Beulah
Mandaree
Fort Berthold Reservation
Killdeer
Dunn Center
Halliday
Little Muddy River
White Earth River
Shell Creek
Little Missouri River
Knife River
Missouri River

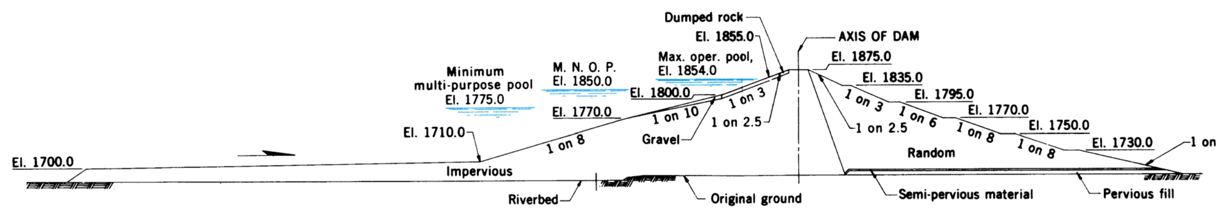
Plate II-18



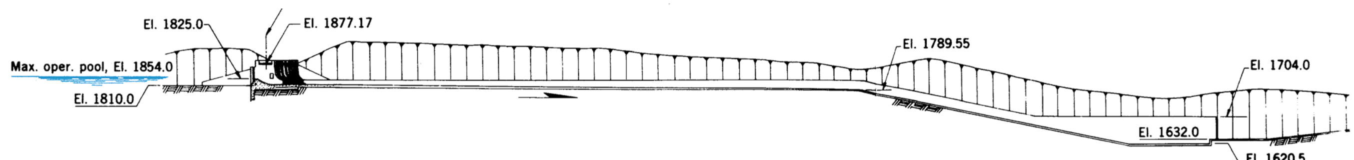
PLAN



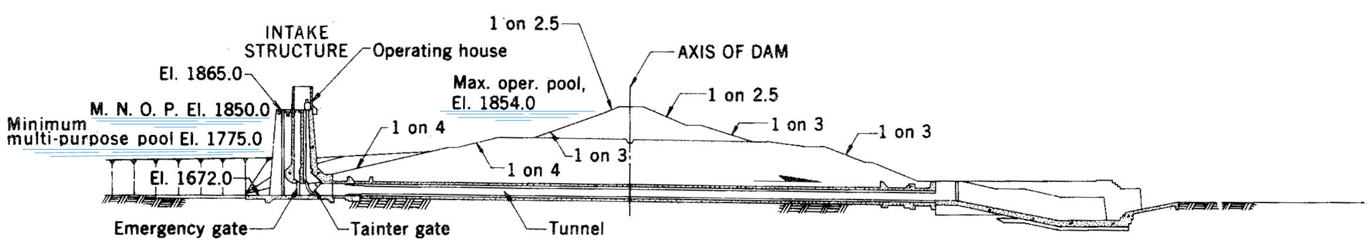
POWERHOUSE SECTION



EMBANKMENT SECTION



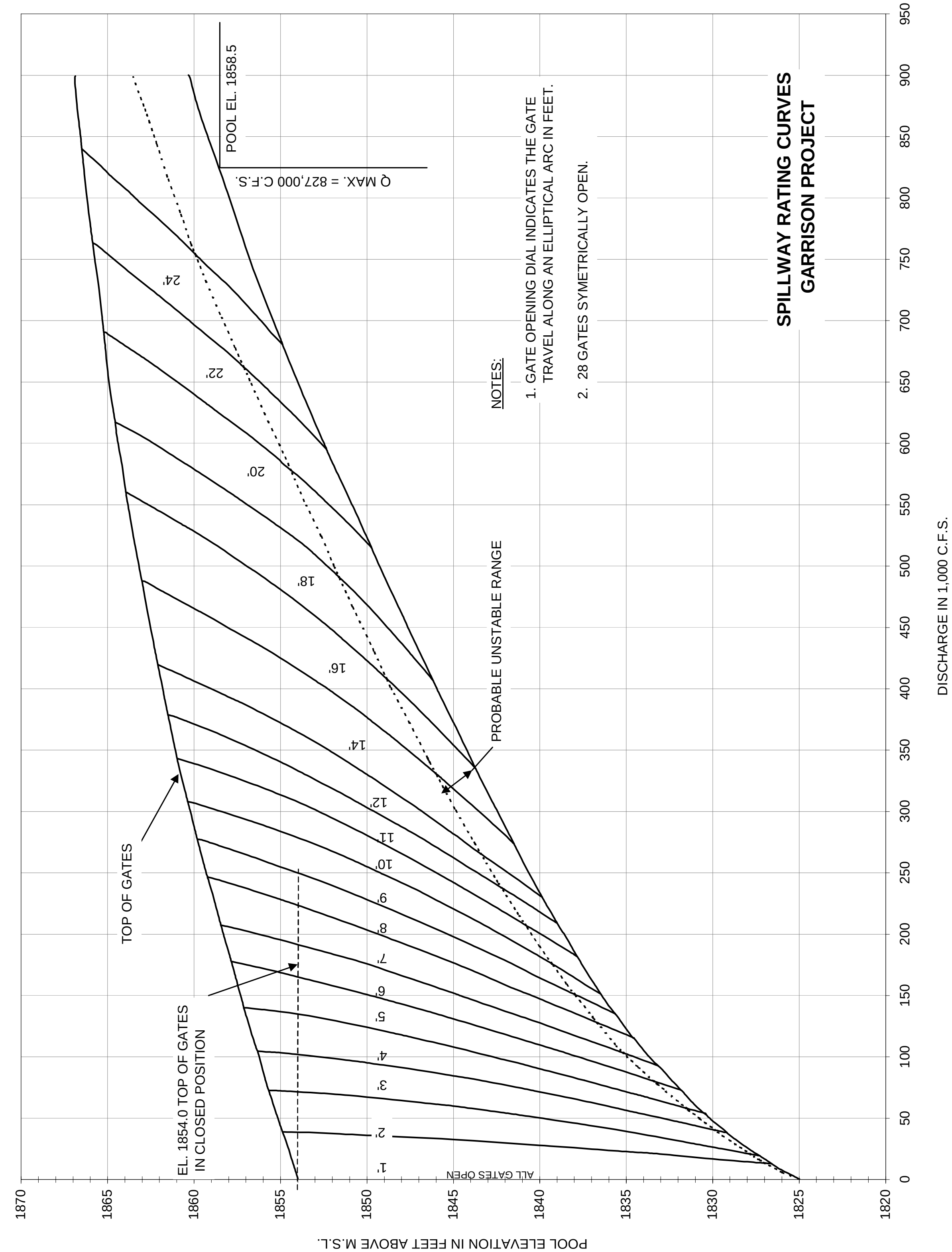
SPILLWAY PROFILE



OUTLET WORKS PROFILE

Missouri River Basin
Garrison Dam
Lake Sakakawea
Flood Control Project

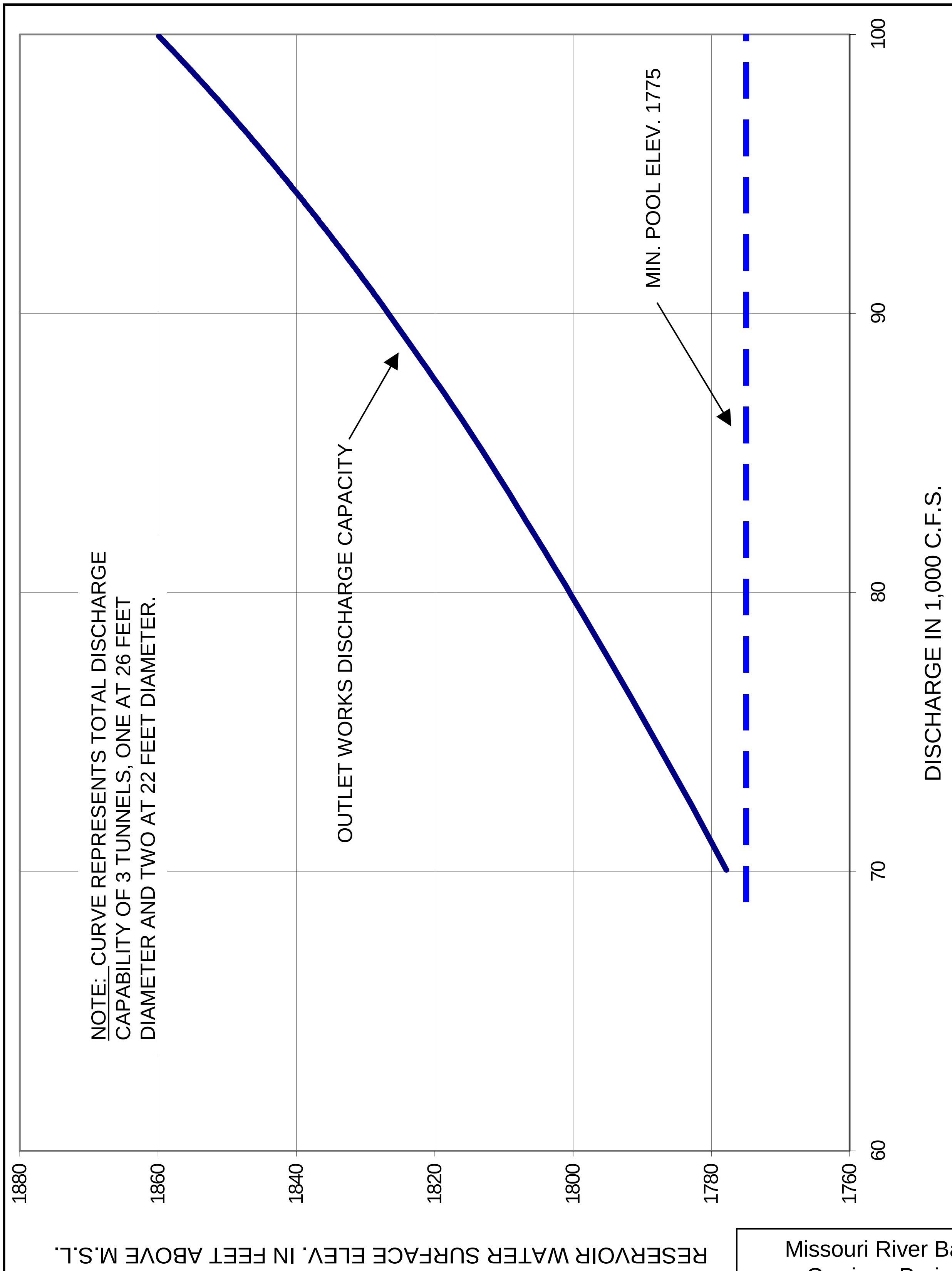
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
Spillway Rating Curves
Garrison Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

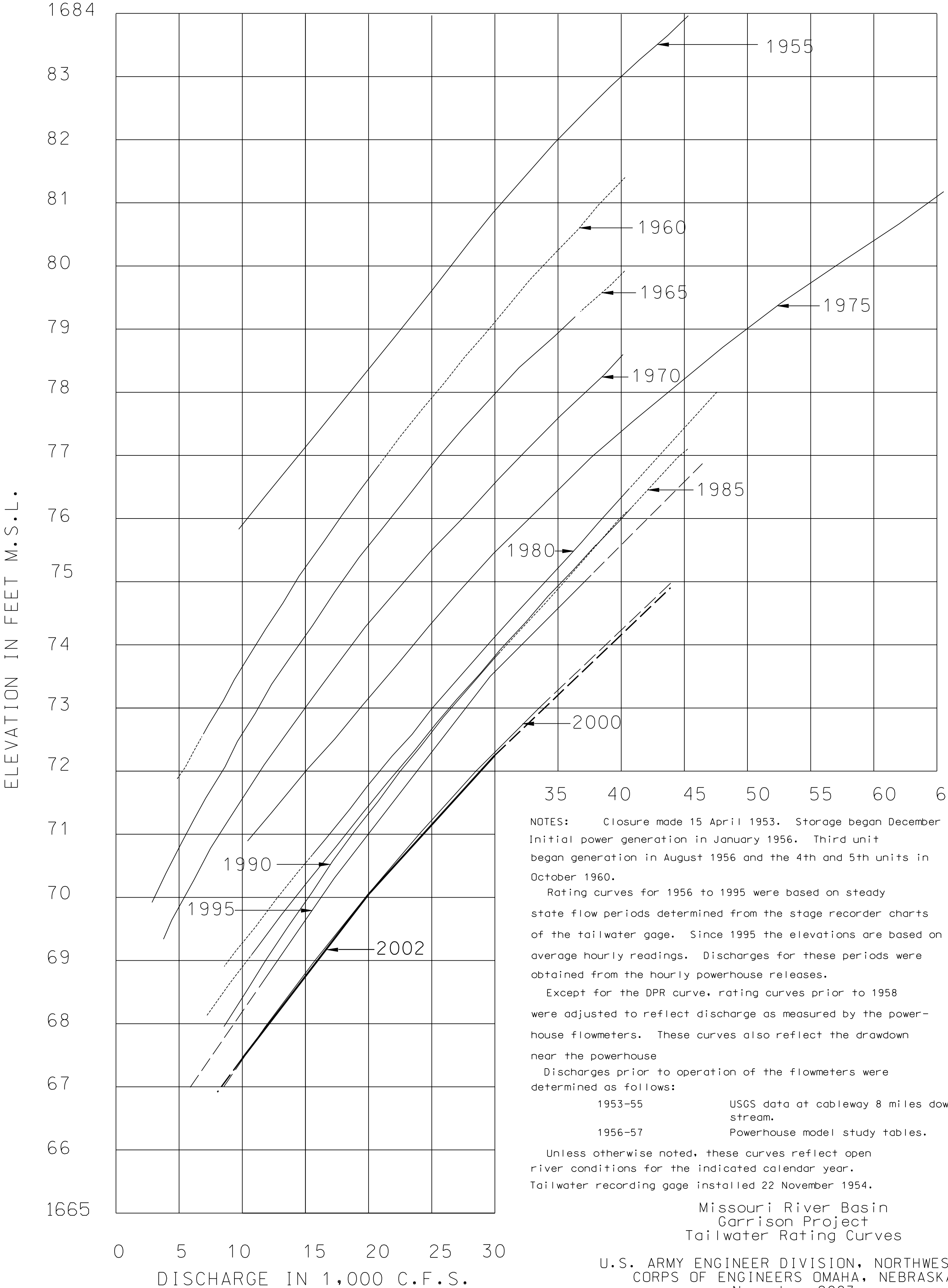
Plate II-20



Missouri River Basin
Garrison Project
Discharge Rating Curve for
Flood Control Tunnels

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-21



NOTES: Closure made 15 April 1953. Storage began December 1953. Initial power generation in January 1956. Third unit began generation in August 1956 and the 4th and 5th units in October 1960.

Rating curves for 1956 to 1995 were based on steady state flow periods determined from the stage recorder charts of the tailwater gage. Since 1995 the elevations are based on average hourly readings. Discharges for these periods were obtained from the hourly powerhouse releases.

Except for the DPR curve, rating curves prior to 1958 were adjusted to reflect discharge as measured by the power-house flowmeters. These curves also reflect the drawdown near the powerhouse

Discharges prior to operation of the flowmeters were determined as follows:

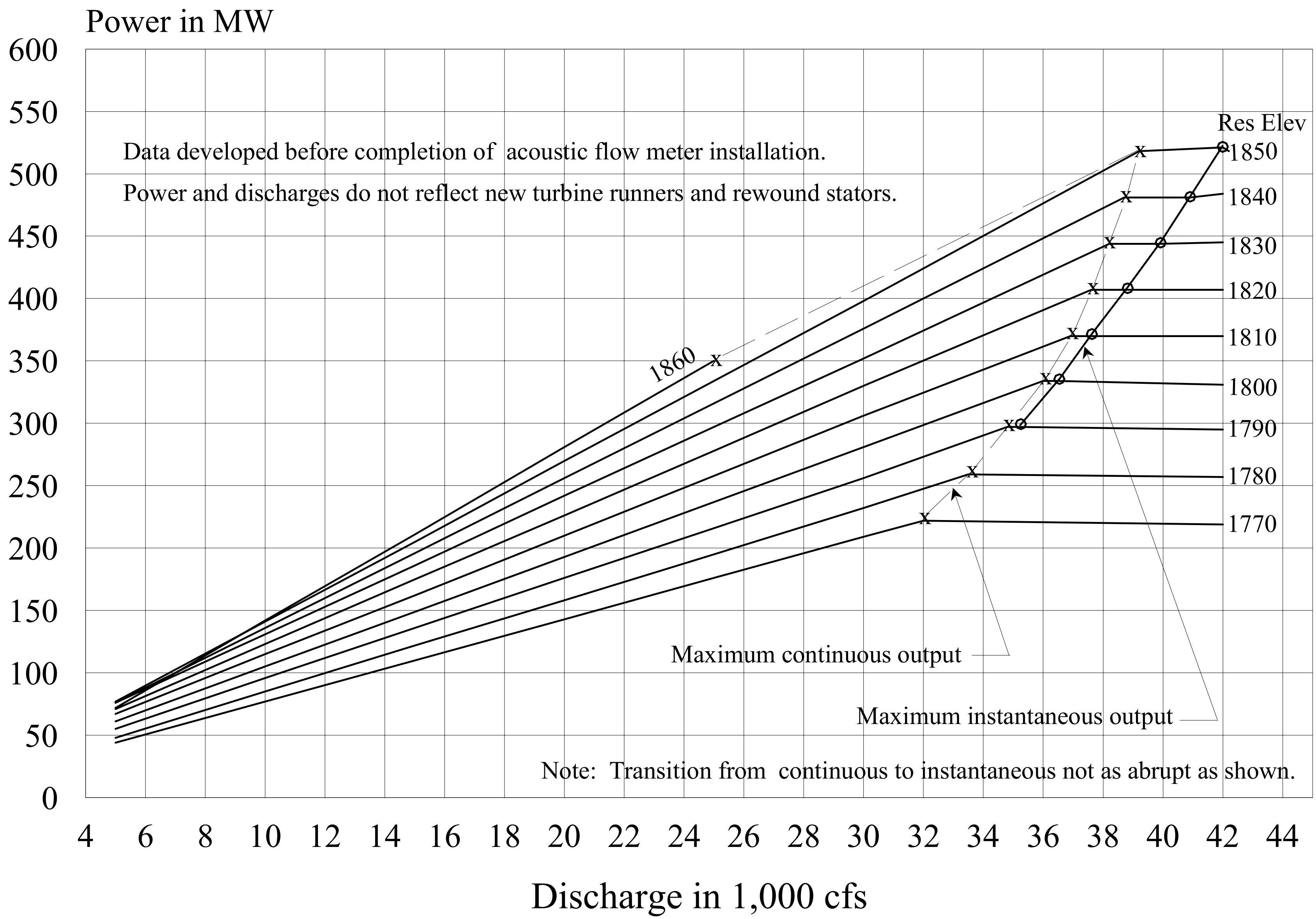
1953-55	USGS data at cableway 8 miles down stream.
1956-57	Powerhouse model study tables.

Unless otherwise noted, these curves reflect open river conditions for the indicated calendar year.
Tailwater recording gage installed 22 November 1954.

Missouri River Basin
Garrison Project
Tailwater Rating Curves

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS OMAHA, NEBRASKA
November 2003
Plate II-22

Garrison Powerplant



AREA IN ACRES
1988 SURVEY

ELEV	0	1	2	3	4	5	6	7	8	9
1660	0	0	0	0	0	0	0	0	11	18
1670	31	33	25	38	73	129	207	306	426	568
1680	626	527	421	429	551	785	1134	1596	2171	2861
1690	3464	3786	4033	4408	4910	5539	6297	7181	8192	9332
1700	10427	11286	12056	12900	13818	14810	15876	17015	18228	19515
1710	20738	21767	22747	23822	24989	26249	27603	29050	30590	32223
1720	33765	35042	36261	37612	39097	40715	42465	44349	46366	48516
1730	50705	52781	54754	56690	58590	60453	62280	64071	65825	67543
1740	69283	71106	72954	74768	76546	78290	80000	81675	83316	84922
1750	86512	88120	89756	91411	93083	94774	96483	98210	99955	101719
1760	103501	105286	107056	108805	110531	112236	113920	115582	117222	118840
1770	120369	121785	123227	124787	126465	128261	130174	132206	134355	136623
1780	138809	140716	142545	144494	146566	148759	151073	153509	156066	158744
1790	161295	163491	165610	167913	170400	173070	175923	178959	182180	185583
1800	188998	192191	195248	198311	201379	204453	207531	210620	213710	216805
1810	219955	223165	226365	229505	232585	235600	238545	241430	244255	247015
1820	249665	252215	254825	257585	260485	263525	266715	270055	273535	277160
1830	280520	283270	285940	288985	292410	296210	300380	304925	309845	315145
1840	320600	325805	330710	335450	340035	344460	348715	352810	356740	360505
1850	364265	368210	372275	376345	380415	384480	388545	392615	396685	400750
1860	404810									

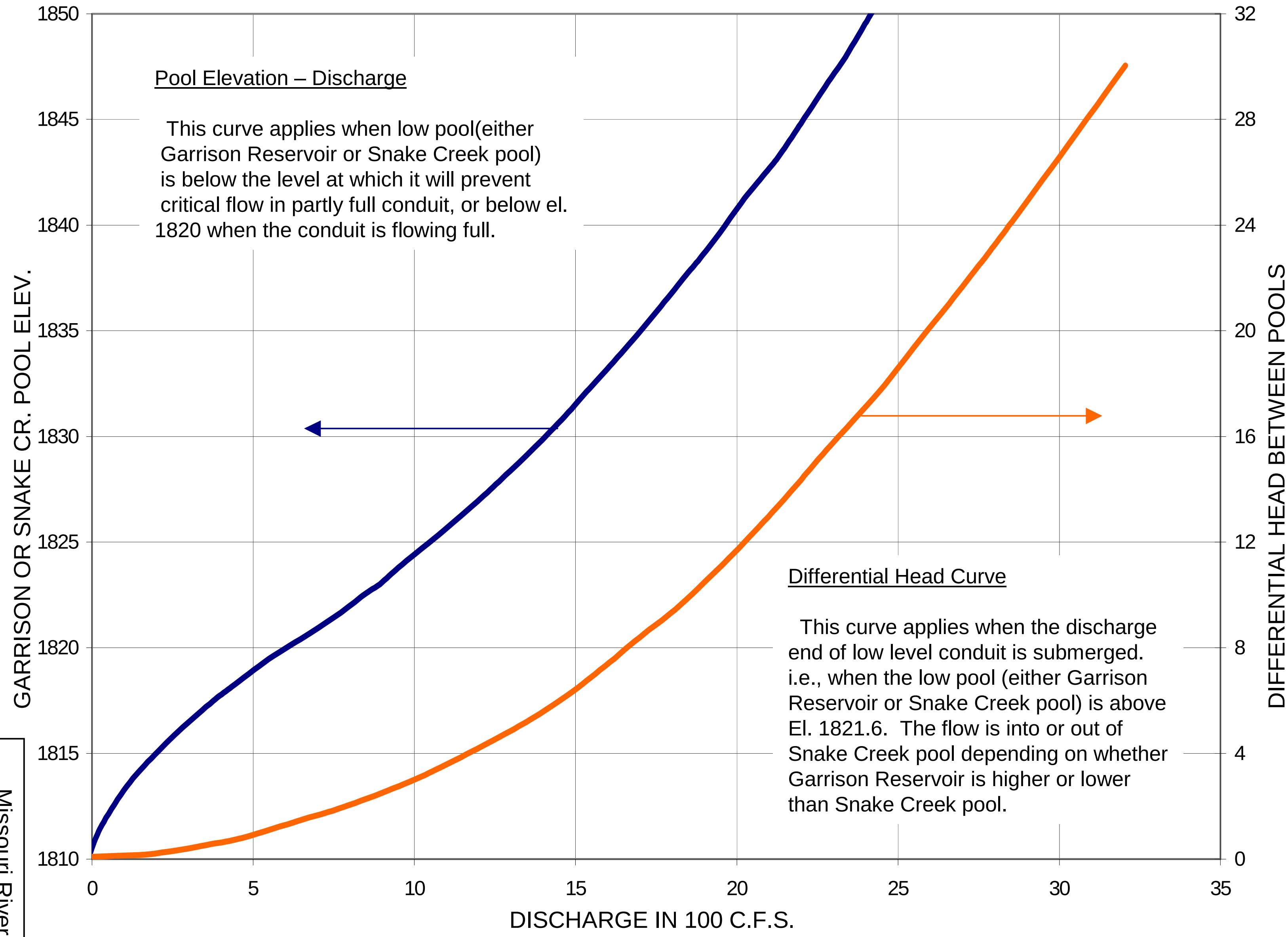
CAPACITY IN ACRE-FEET
1988 SURVEY

ELEV	0	1	2	3	4	5	6	7	8	9
1660	0	0	0	0	0	0	0	0	7	22
1670	43	85	109	135	186	282	445	697	1058	1550
1680	2194	2802	3248	3645	4107	4747	5678	7015	8870	11358
1690	14592	18286	22164	26352	30980	36173	42059	48767	56422	65152
1700	75086	86006	97658	110118	123459	137755	153080	169507	187110	205964
1710	226141	247441	269675	292936	317319	342914	369817	398121	427918	459301
1720	492365	526831	562450	599353	637675	677548	719105	762479	807804	855212
1730	904837	956622	1010399	1066130	1123779	1183310	1244686	1307871	1372828	1439521
1740	1507914	1578088	1650127	1723997	1799663	1877090	1956244	2037091	2119595	2203723
1750	2289440	2376747	2465681	2556260	2648503	2742427	2838051	2935393	3034471	3135304
1760	3237910	3342306	3448483	3556419	3666093	3777482	3890566	4005322	4121730	4239767
1770	4359411	4480505	4602982	4726959	4852556	4979890	5109078	5240239	5373490	5508950
1780	5646736	5786568	5928169	6071658	6217158	6364791	6514677	6666938	6821695	6979070
1790	7139184	7301661	7466166	7632882	7801993	7973682	8148133	8325528	8506052	8689888
1800	8877219	9067884	9261602	9458380	9658224	9861138	10067130	10276200	10488370	10703620
1810	10921980	11143530	11368310	11596260	11827320	12061430	12298520	12538520	12781380	13027030
1820	13275410	13526360	13779840	14036010	14295010	14556980	14822060	15090410	15362170	15637480
1830	15916490	16198520	16483030	16770400	17061000	17355220	17653420	17955980	18263270	18575670
1840	18893560	19216870	19545170	19878290	20216070	20558360	20904990	21255790	21610610	21969270
1850	22331620	22697800	23068040	23442350	23820730	24203180	24589690	24980270	25374920	25773640
1860	26176420									

Missouri River Basin
Garrison Area-Capacity Tables

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-24



Missouri River Basin
Conduit Rating Curves for
Snake Creek Embankment

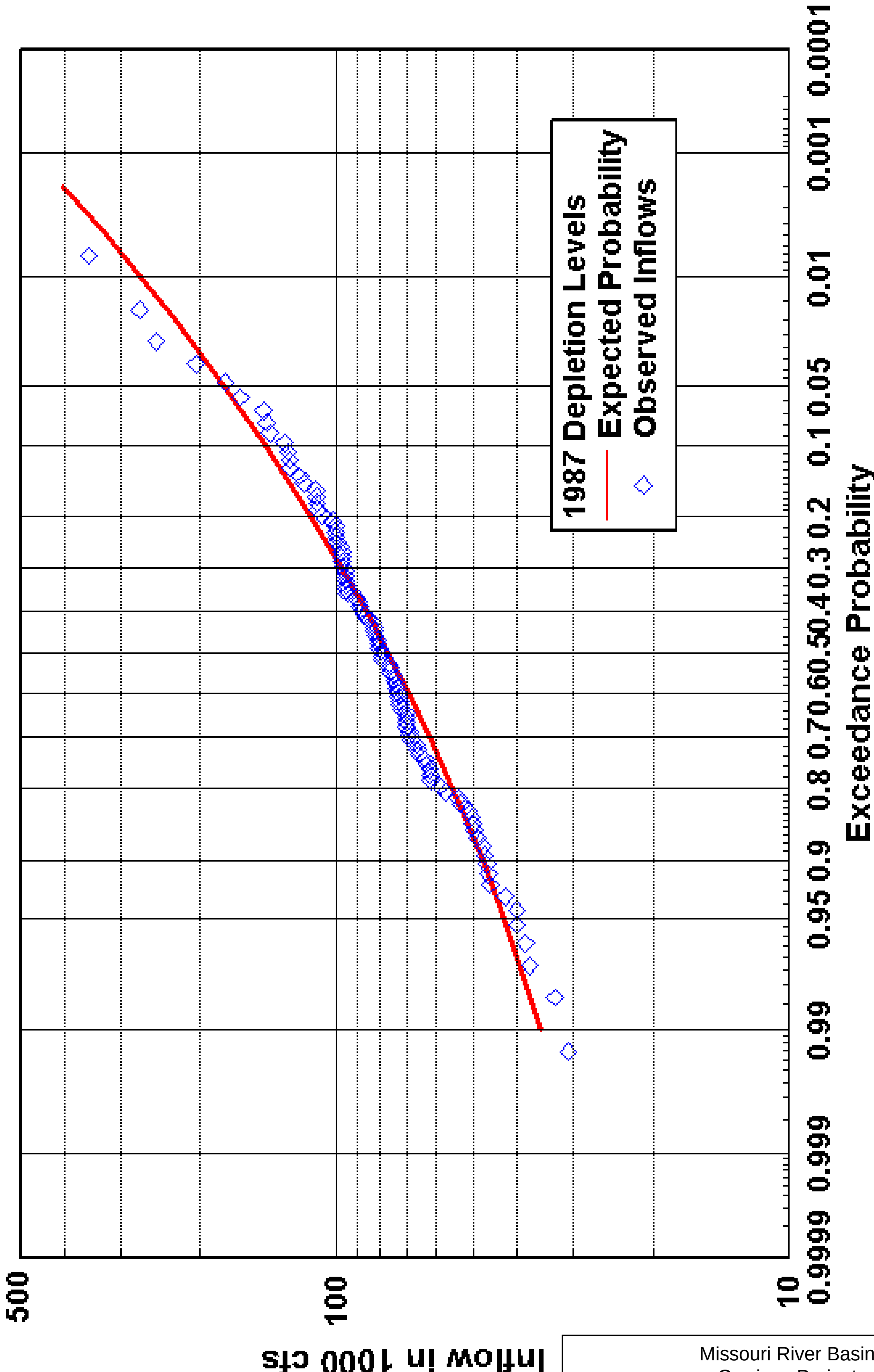
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-25

Missouri River Basin
Garrison Project
Embankment, Intakes,
Spillway, and Powerhouse

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

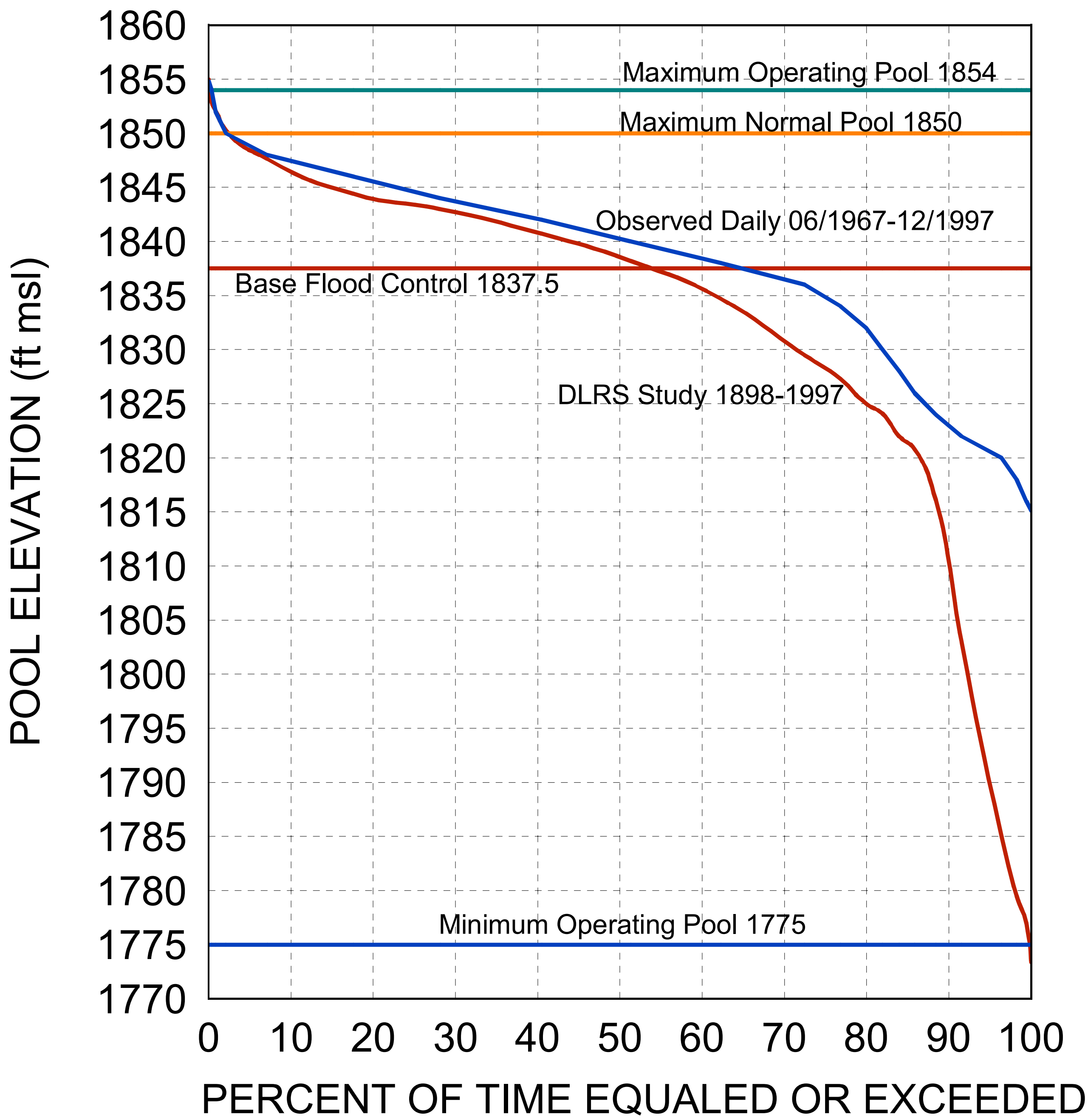
Plate II-26



Missouri River Basin
Garrison Project
Inflow Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

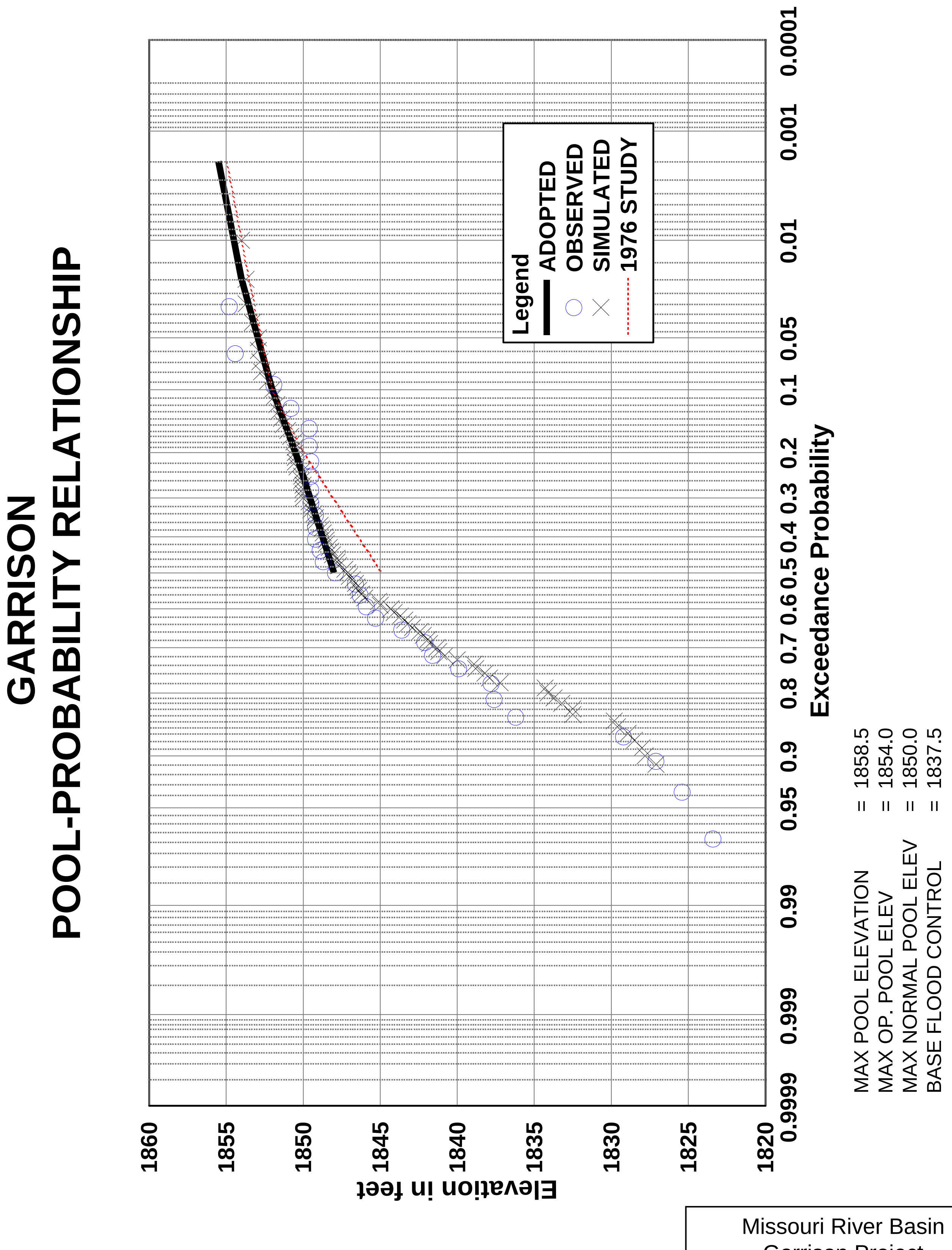
LAKE SAKAKAWEA

POOL DURATION RELATIONSHIP



Missouri River Basin
Garrison Dam Pool Elevation Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-28

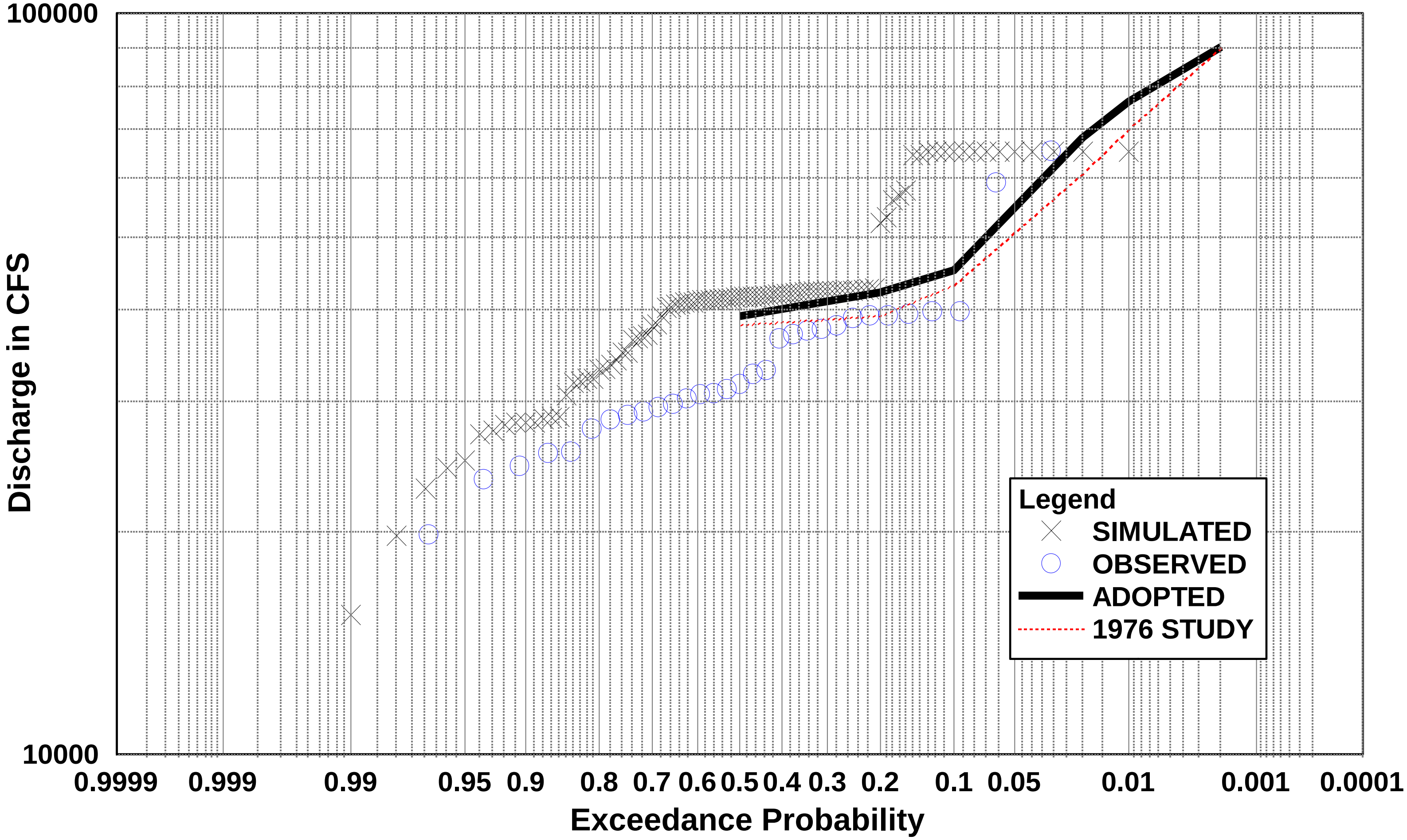


Missouri River Basin
Garrison Project
Pool-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-29

GARRISON
RELEASE-PROBABILITY RELATIONSHIP

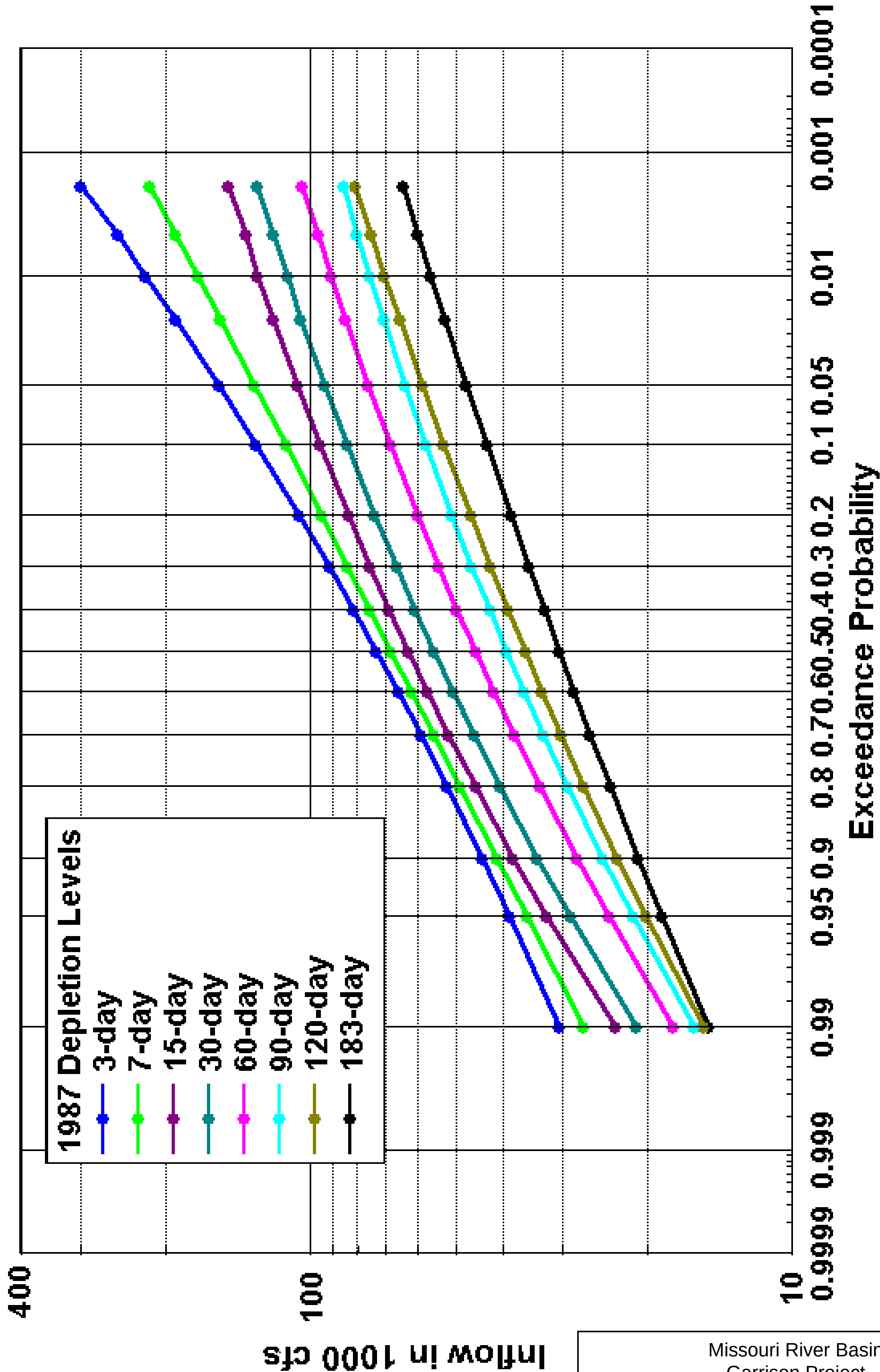


POWER PLANT CAPACITY = 38,000
OUTLET CAPACITY = 98,000
SPILLWAY CAPACITY = 827,000

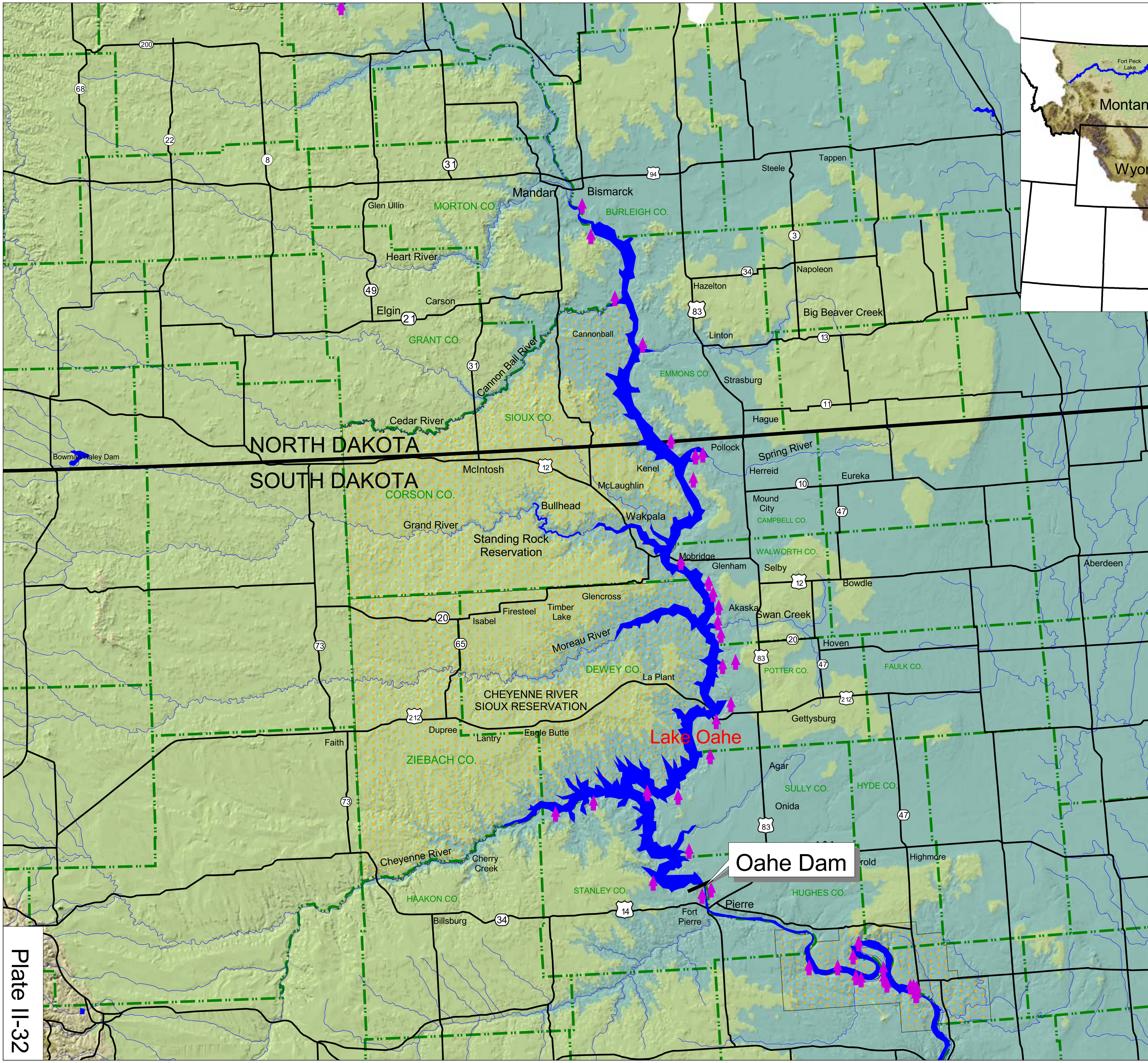
Missouri River Basin
Garrison Project
Release-Probability Relationship

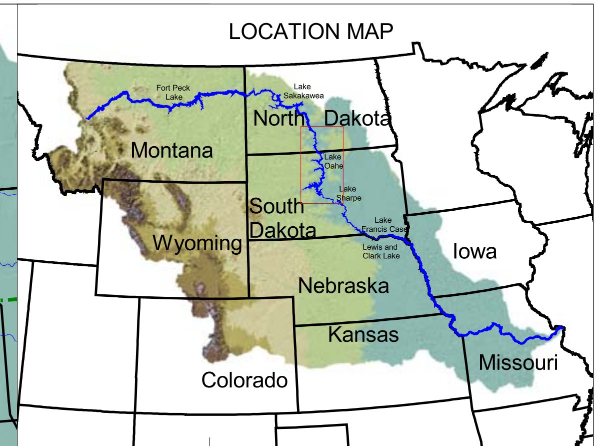
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-30



Missouri River Basin
Garrison Project
Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



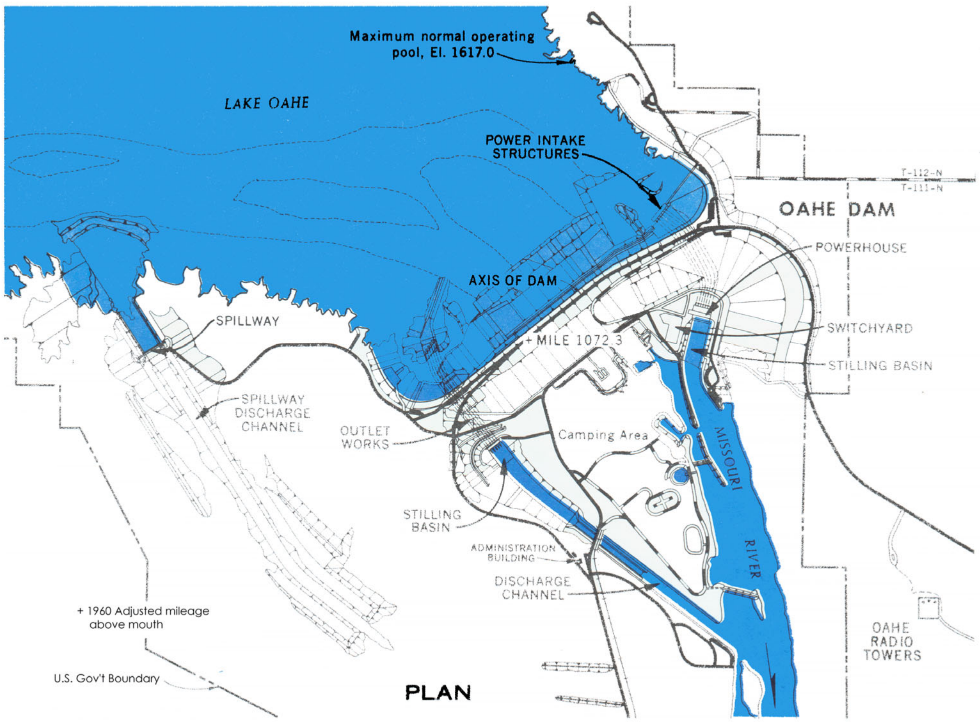


U.S. Army Corps of Engineers

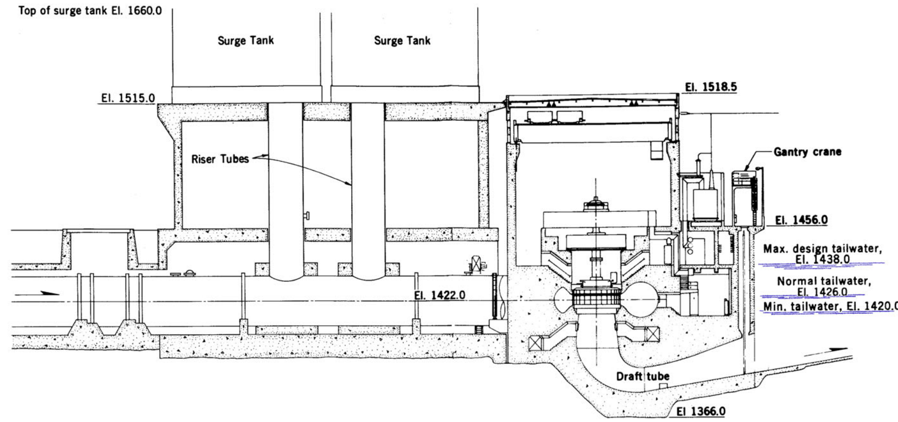
OAHE DAM
LAKE OAHE
MISSOURI RIVER BASIN
NORTH AND SOUTH DAKOTA

U.S. ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA

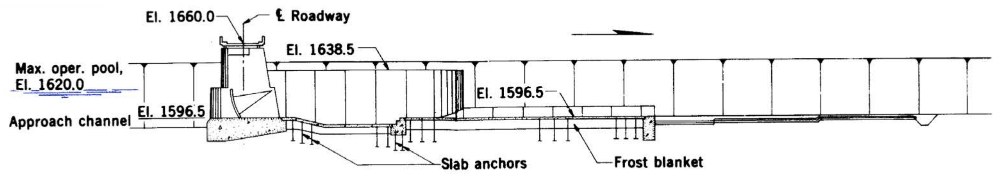
Plate II-32



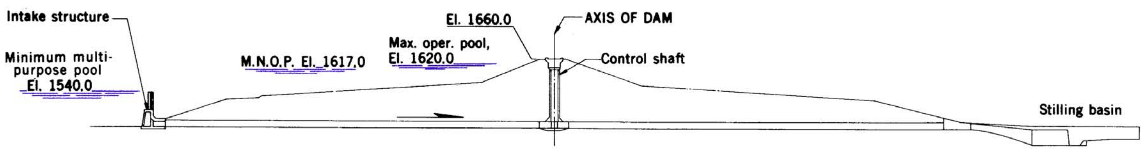
PLAN



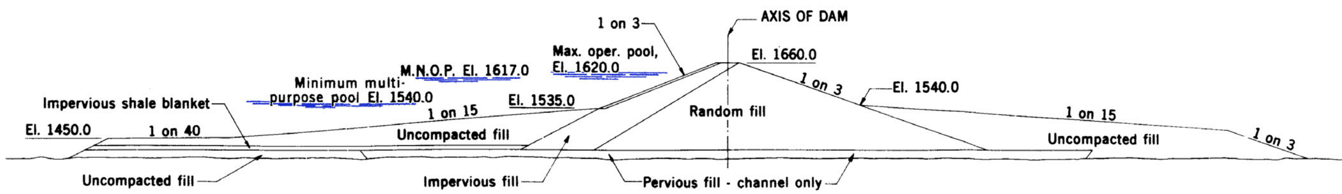
POWERHOUSE SECTION



SPILLWAY PROFILE



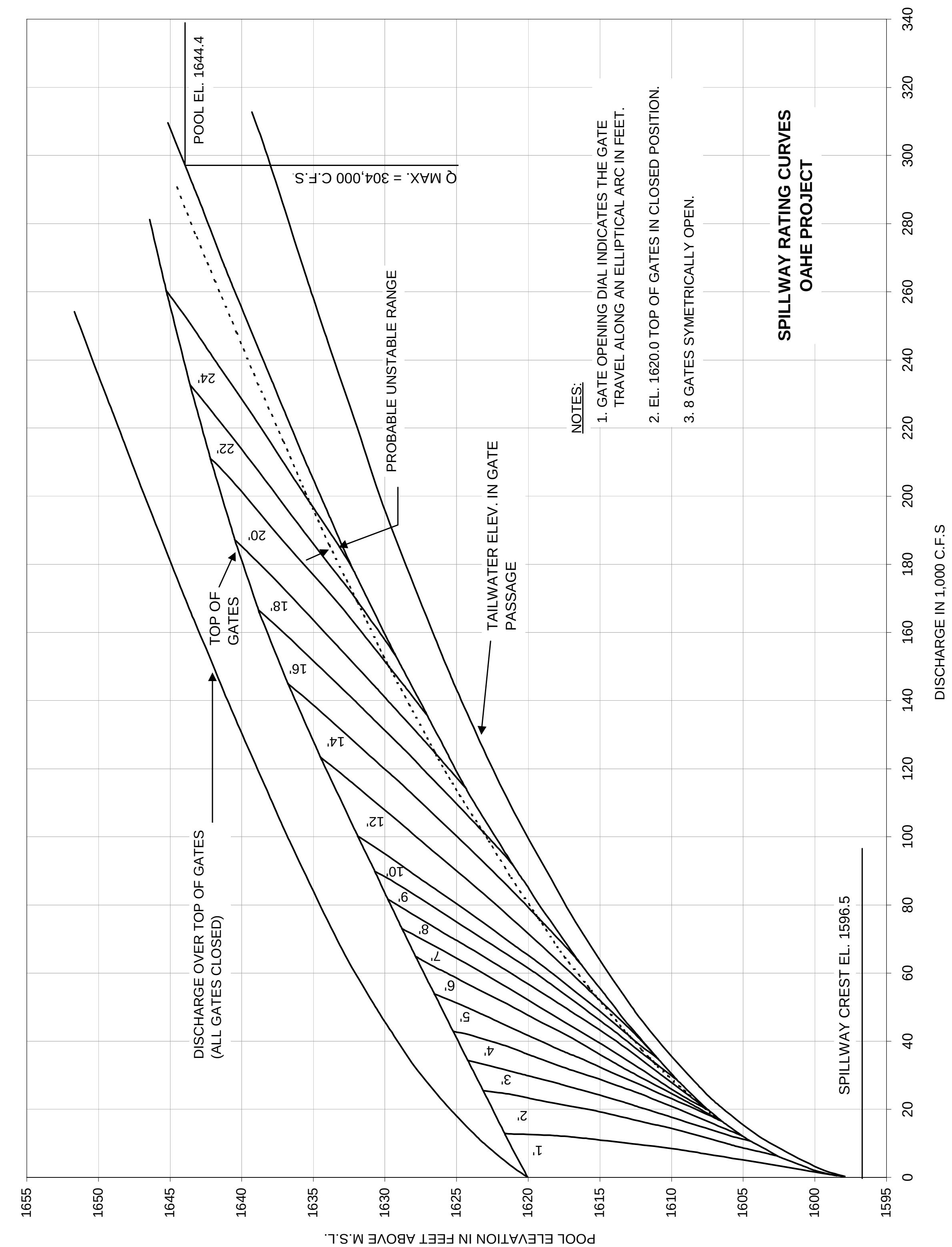
OUTLET WORKS PROFILE
FLOOD CONTROL TUNNELS



EMBANKMENT SECTION

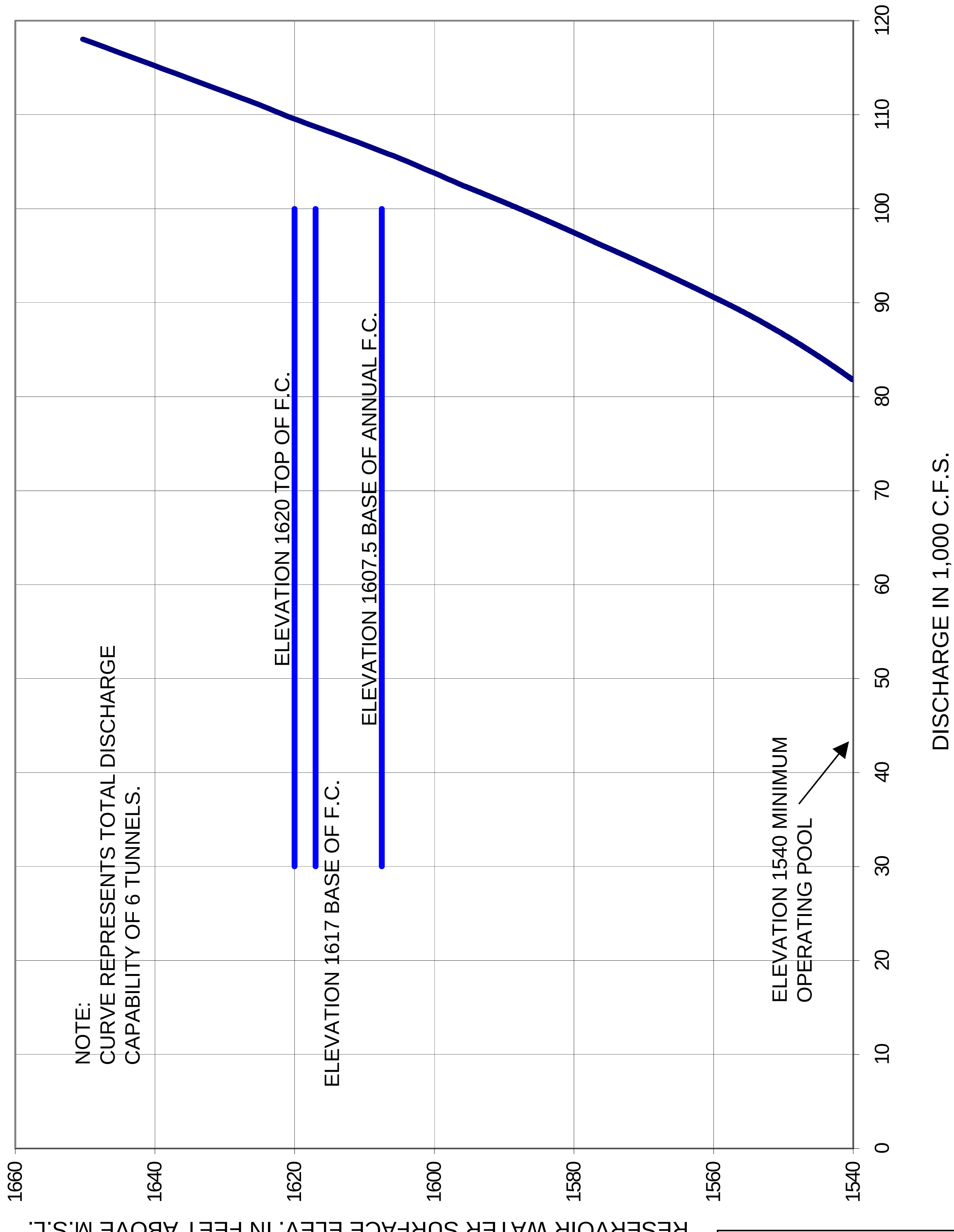
Missouri River Basin
Oahe Dam
Lake Oahe
Flood Control Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
Spillway Rating Curves
Oahe Project

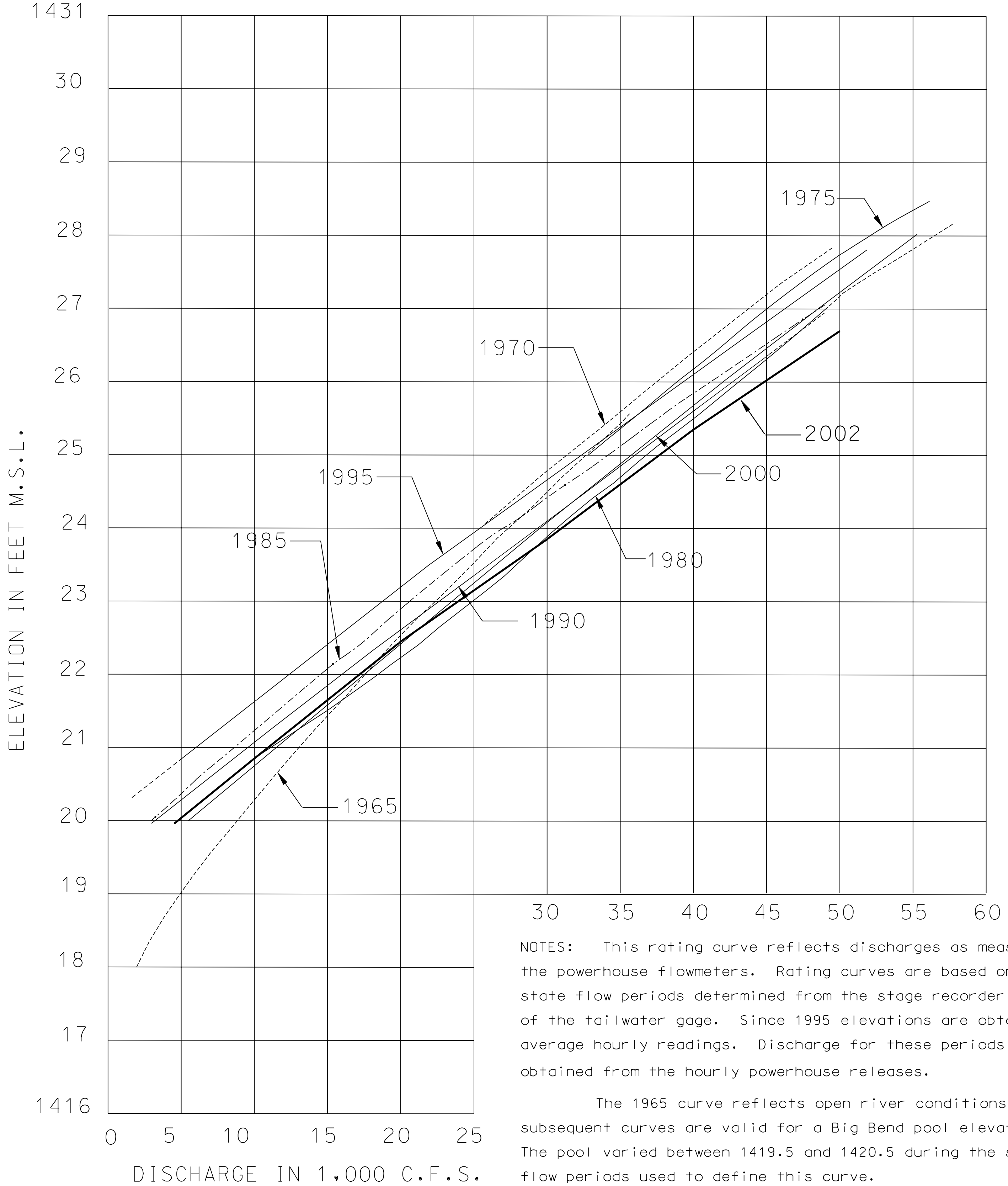
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
Oahe Project
Outlet Works Rating Curve

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-35



NOTES: This rating curve reflects discharges as measured by the powerhouse flowmeters. Rating curves are based on steady state flow periods determined from the stage recorder charts of the tailwater gage. Since 1995 elevations are obtained from average hourly readings. Discharge for these periods were obtained from the hourly powerhouse releases.

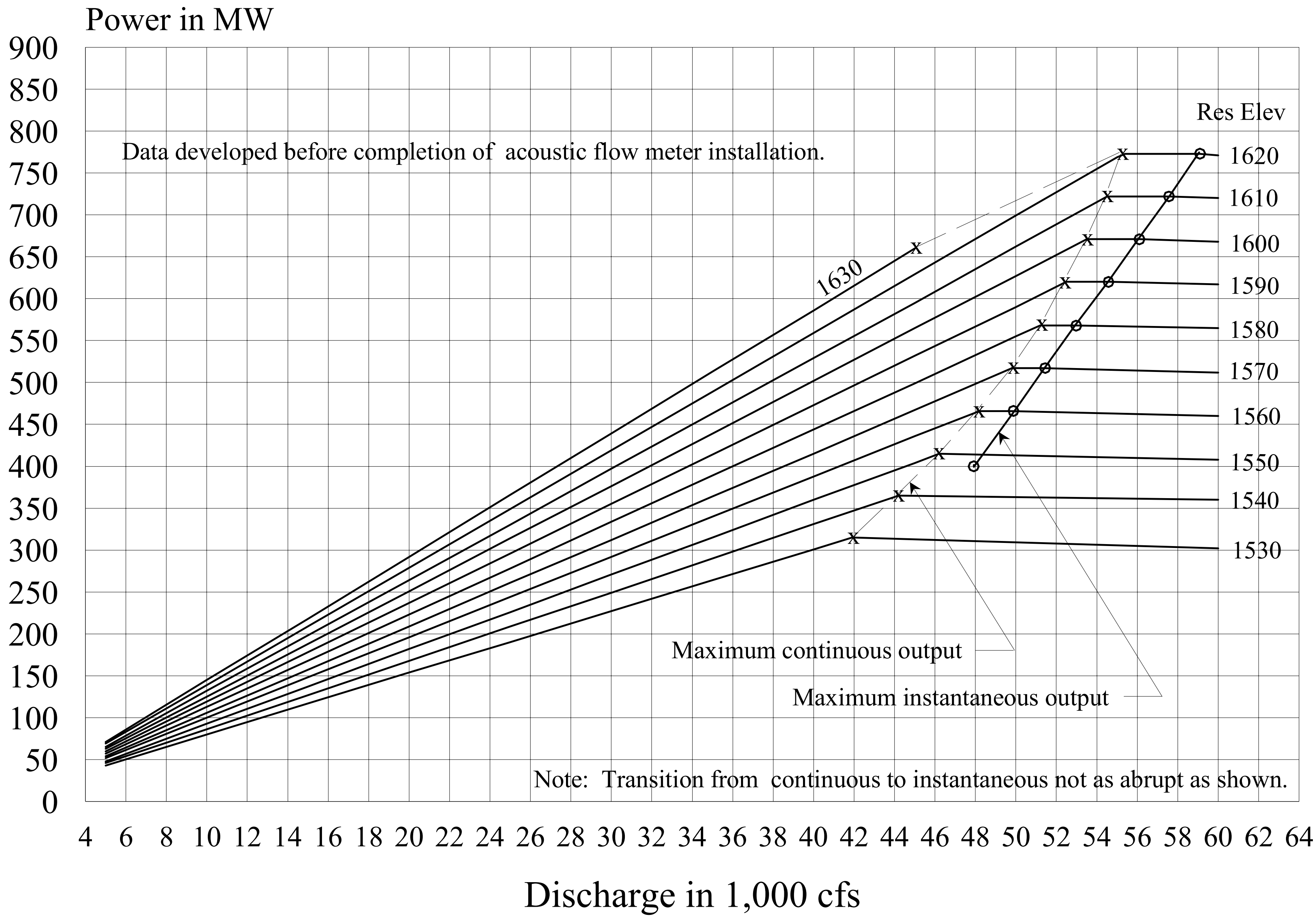
The 1965 curve reflects open river conditions. All subsequent curves are valid for a Big Bend pool elevation of 1420. The pool varied between 1419.5 and 1420.5 during the steady state flow periods used to define this curve.

The construction of channel block No. 6 was completed 15 June 1967. An extension of channel block No. 6 to River Island was completed 12 July 1970.

Missouri River Basin
Oahe Project
Tailwater Rating Curves

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS OMAHA, NEBRASKA
November 2003
Plate II-36

Oahe Powerplant



Missouri River Basin
Oahe Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Area in Acres
(1989 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1410	0	0	0	0	0	0	0	0	0	36
1420	107	163	213	323	493	723	1013	1363	1773	2244
1430	2687	3010	3291	3615	3983	4393	4846	5343	5882	6464
1440	6995	7390	7759	8202	8717	9306	9968	10703	11512	12394
1450	13282	14087	14836	15585	16332	17078	17823	18567	19310	20051
1460	20735	21329	21930	22610	23366	24200	25111	26101	27167	28310
1470	29475	30573	31611	32629	33628	34606	35565	36505	37425	38325
1480	39166	39937	40730	41602	42551	43578	44684	45868	47130	48470
1490	49835	51138	52380	53597	54790	55958	57102	58221	59316	60386
1500	61420	62431	64363	64541	65663	66830	68043	69300	70602	71949
1510	73319	74667	75978	77264	78525	79759	80968	82152	83310	84443
1520	85462	86338	87246	88302	89506	90858	92359	94008	95804	97749
1530	99705	101487	103157	104828	106502	108177	109855	111534	113215	114898
1540	116560	118188	119817	121473	123158	124869	126609	128376	130170	131992
1550	133628	134938	136247	137809	139623	141688	144006	146575	149397	152470
1560	155510	158173	160653	163205	165828	168523	171290	174129	177039	180020
1570	182933	185647	188313	191075	193945	196915	199980	203150	206415	209780
1580	213150	216375	219525	222695	225880	229085	232310	235550	238805	242080
1590	245190	248035	250880	253940	257220	260715	264425	268350	272495	276855
1600	281010	284570	287995	291710	295720	300030	304630	309525	314715	320200
1610	325965	331080	336170	341175	346105	350960	355740	360435	365055	369600
1620	374135	378760	383445	388130	392815	397500	402185	406875	411555	416240
1630	420930									

Capacity in Acre-Feet
(1989 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1410	0	0	0	0	0	0	0	0	0	13
1420	73	227	400	654	1047	1640	2493	3667	5220	7214
1430	9708	12588	15728	19171	22959	27137	31746	36830	42432	48594
1440	55360	62584	70141	78103	86545	95538	105157	115475	126564	138499
1450	151352	165064	179526	194737	210696	227402	244853	263048	281987	301668
1460	322090	343138	361748	386999	409968	433732	458368	483955	510570	538289
1470	567191	597240	628337	660462	693596	7227718	762809	798849	8355820	873700
1480	912471	852032	992346	1033493	1075550	1118595	1162707	1207963	125443	1302224
1490	1351384	1401895	1453661	1506656	1560856	1616237	1672773	1730441	1789216	1849073
1500	1909988	1971914	2034850	2098841	2163932	2230168	2297593	2366254	2436194	2507459
1510	2580093	2654098	2729427	2806054	2883955	2963104	3043474	3125041	3207779	3291662
1520	3376665	3462587	3549342	3637079	3725947	3816092	3907664	4000811	4095680	4192420
1530	4291179	4391831	4494153	4598145	4703810	4811149	4920165	5030860	5143234	5257290
1540	5373030	5490411	5609407	5730045	5852354	5976361	6102093	6229579	6358845	6489919
1550	6622830	6757176	6892706	7029671	7168325	7308917	7451701	7596929	7744852	7895723
1560	8049792	8206744	8366139	8528051	8692550	8859708	9029597	9202289	9377855	9556367
1570	9737896	9922233	10109190	10298860	10491340	10686750	10885170	11086710	11291470	11499540
1580	11711030	11925840	12143780	12364890	12589170	12816650	13047340	13281270	13518440	13758880
1590	14002600	14249260	14498670	14751020	15006550	15265460	15527980	15794310	16064680	16339300
1600	16618390	16901320	17187530	17477310	17770950	18068750	18371010	18678010	18990060	19307440
1610	19630460	19958970	20292620	20631310	20974970	21323520	21676890	22035000	22397760	22765110
1620	23136960	23513380	23894480	22480270	24670740	25065900	25465740	25870270	26279490	26693380
1630	27111970									

Missouri River Basin
Oahe Area-Capacity Tables

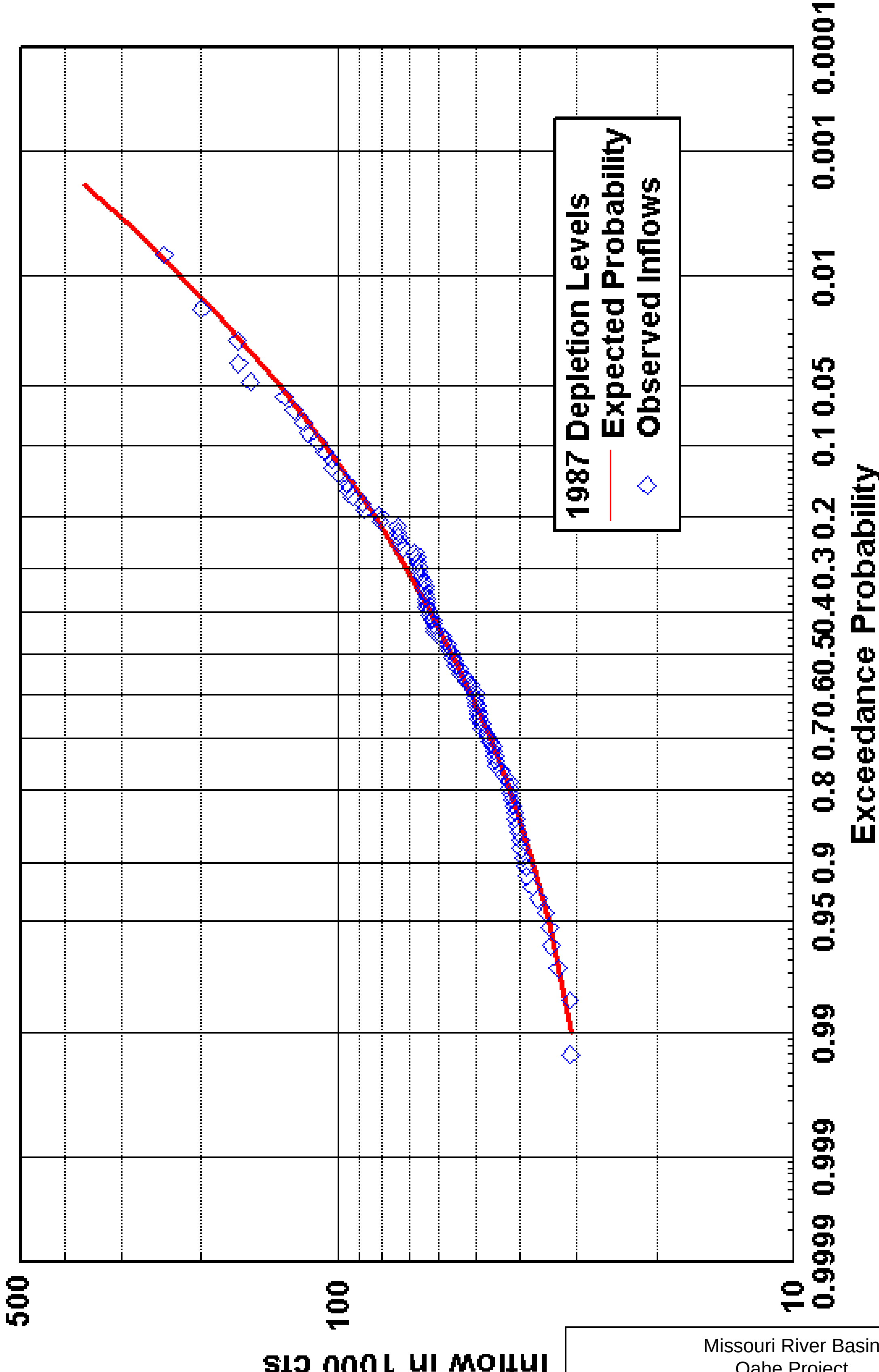
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-38

Missouri River Basin
Oahe Project
Embankment, Intakes,
Powerhouse, and Outlet Works

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

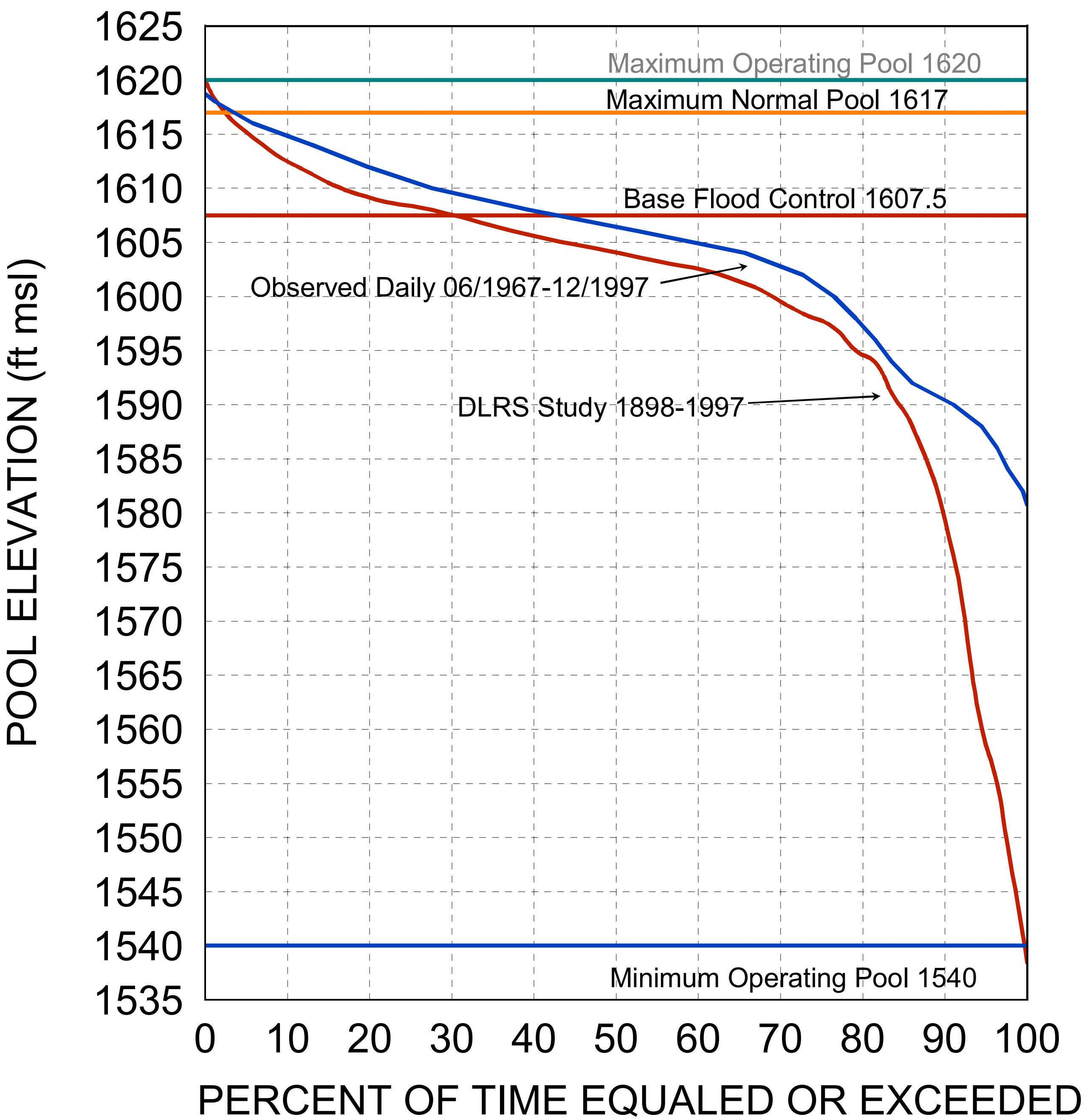
Plate II-39



Missouri River Basin
Oahe Project
Inflow Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

LAKE OAHE

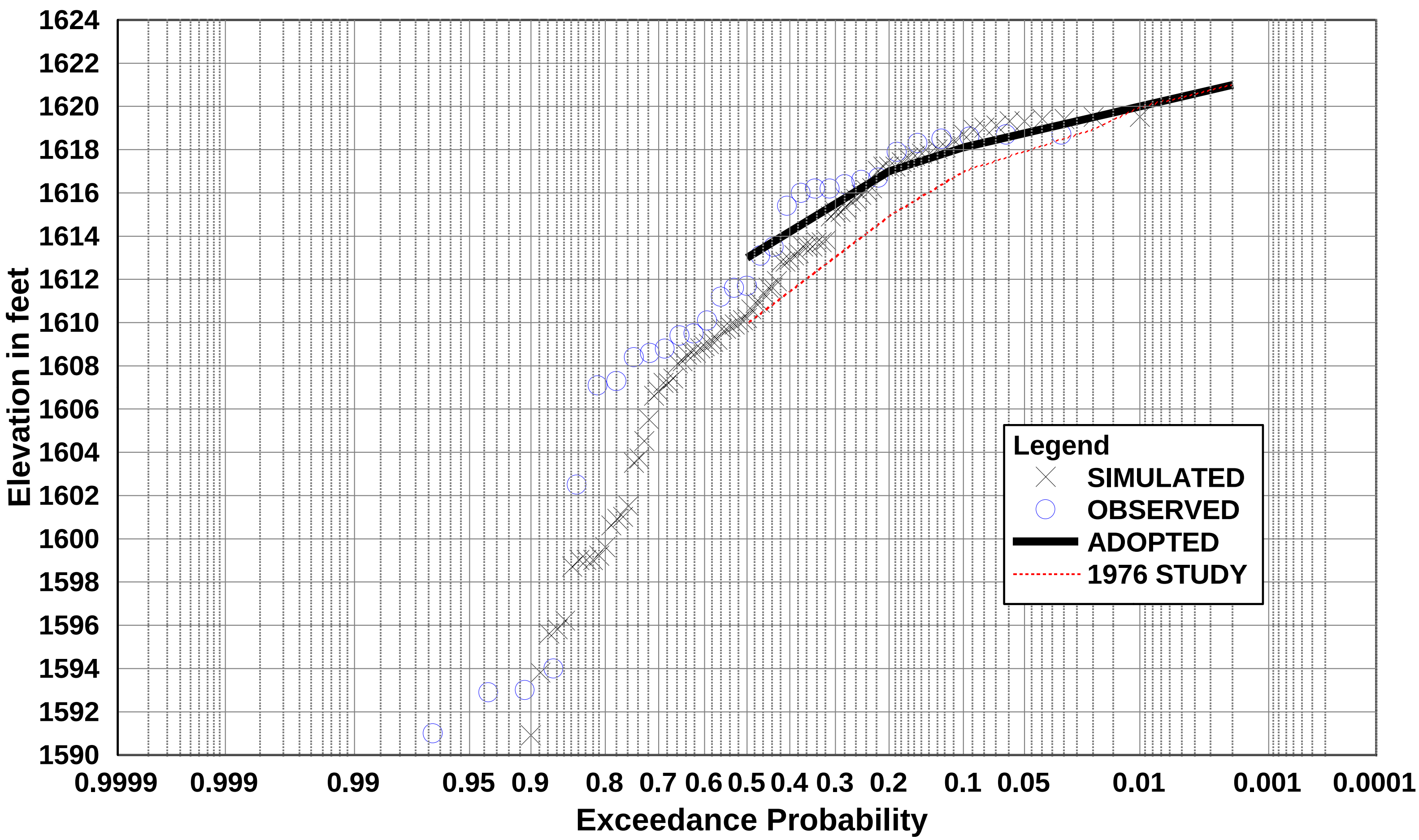
POOL DURATION RELATIONSHIP



Missouri River Basin
Oahe Dam Pool Elevation Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-41

OAHE
POOL-PROBABILITY RELATIONSHIP



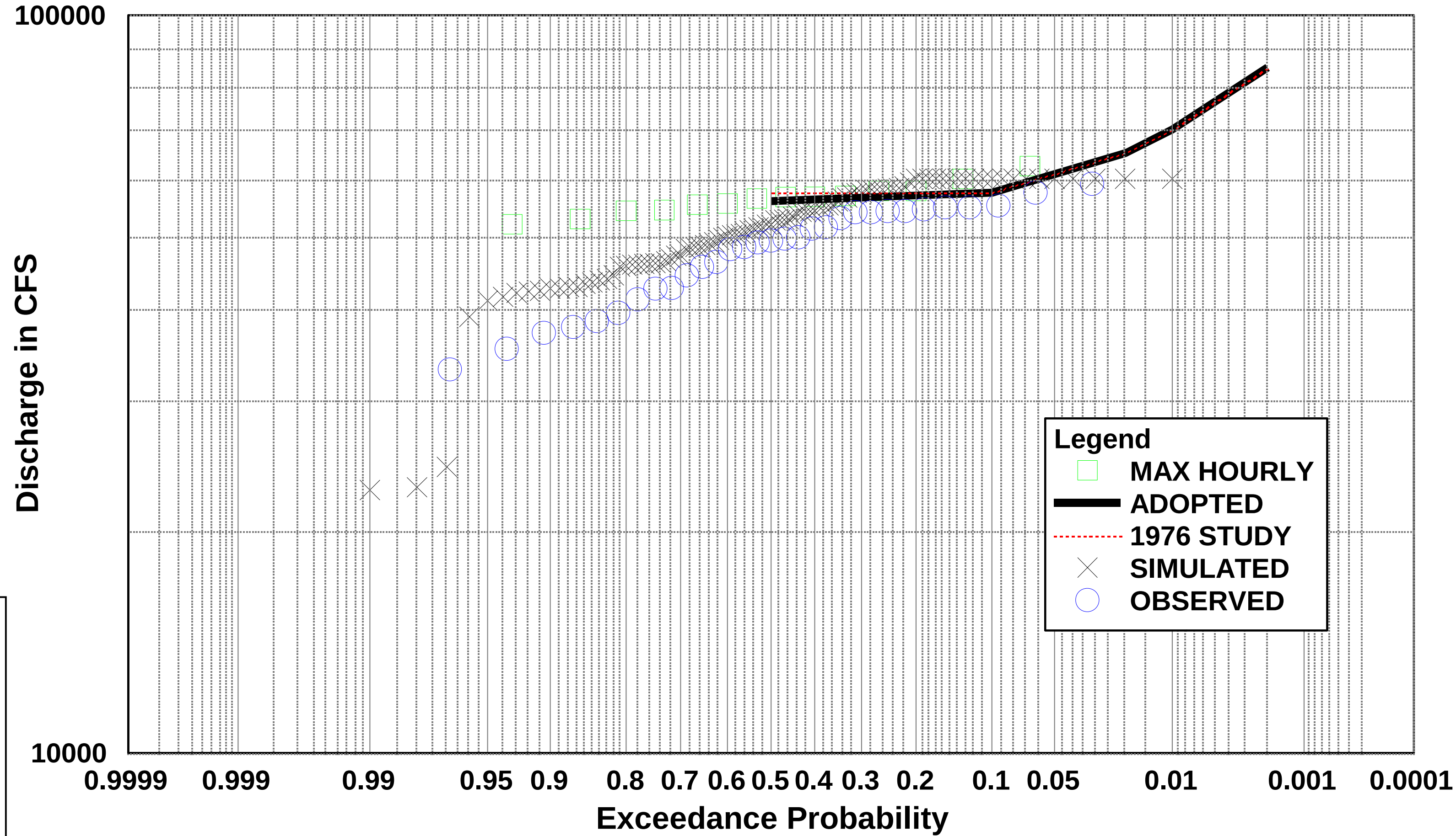
MAX POOL ELEVATION = 1644.4
MAX OP. POOL ELEV = 1620.0
MAX NORMAL POOL ELEV = 1617.0
BASE FLOOD CONTROL = 1607.5

Missouri River Basin
Oahe Project
Pool-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-42

OAHE
RELEASE-PROBABILITY RELATIONSHIP

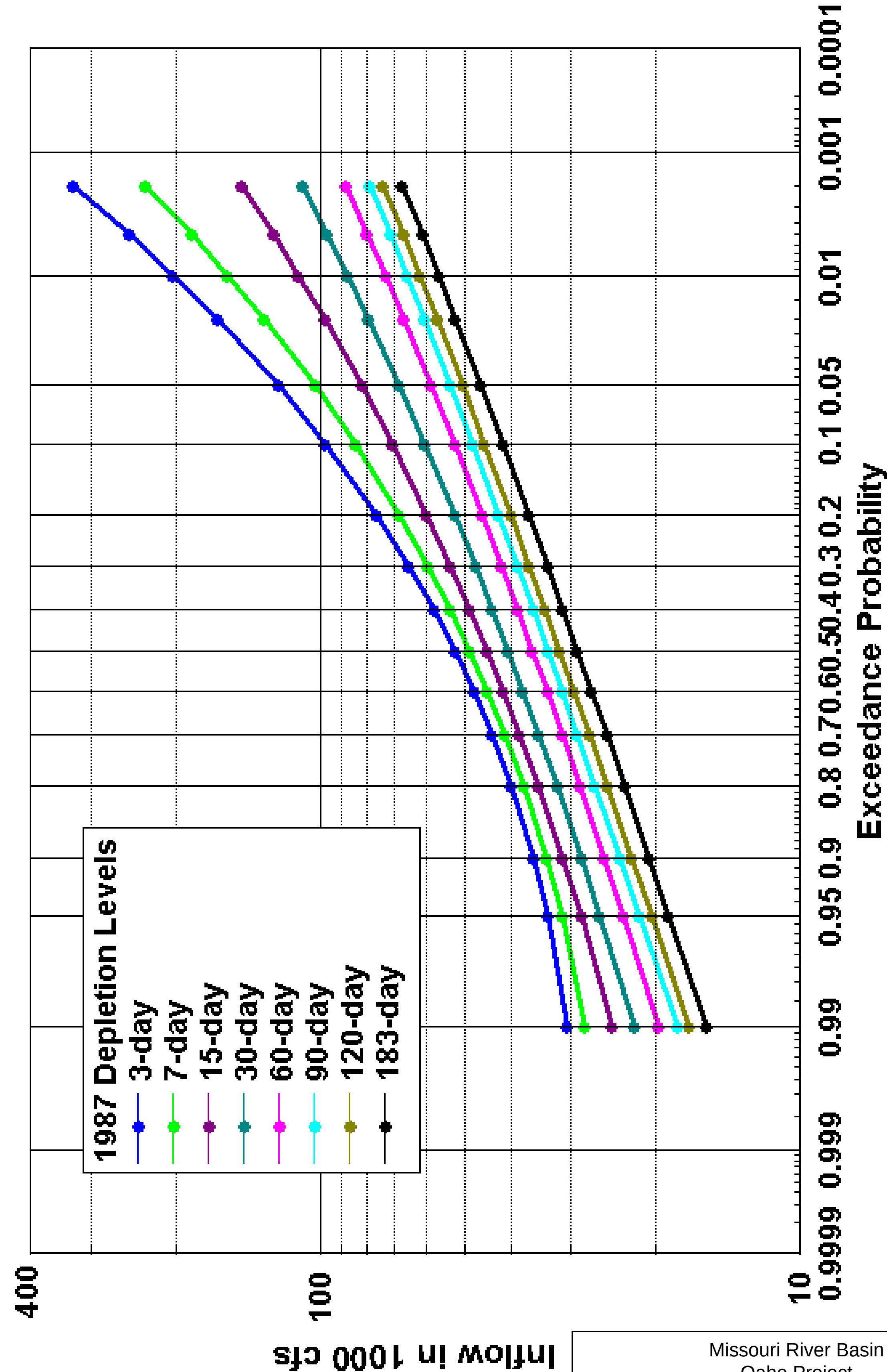


POWER PLANT CAPACITY = 54,000
OUTLET CAPACITY = 111,000
SPILLWAY CAPACITY = 304,000

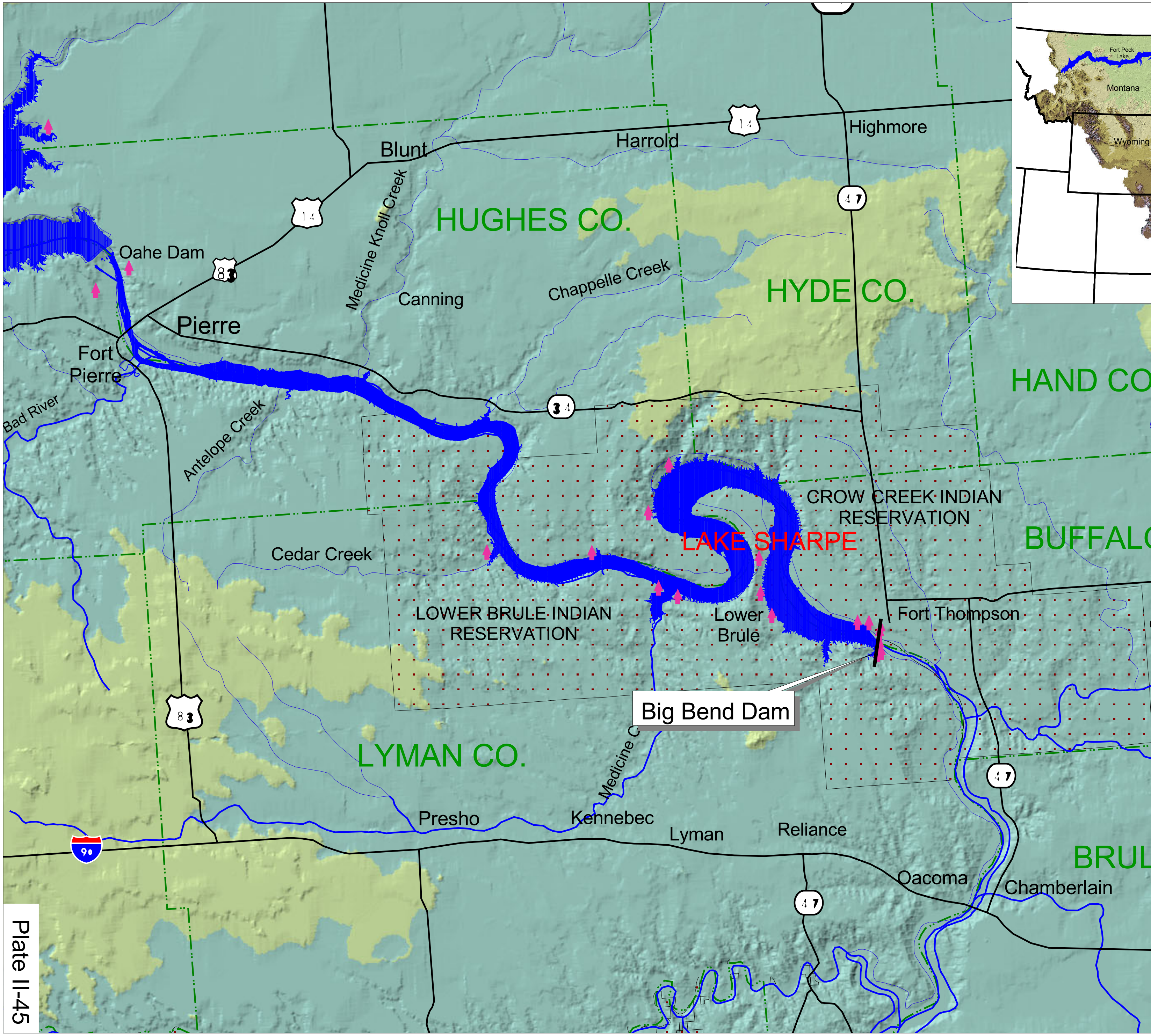
Missouri River Basin
Oahe Project
Release-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-43



Missouri River Basin
Oahe Project
Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

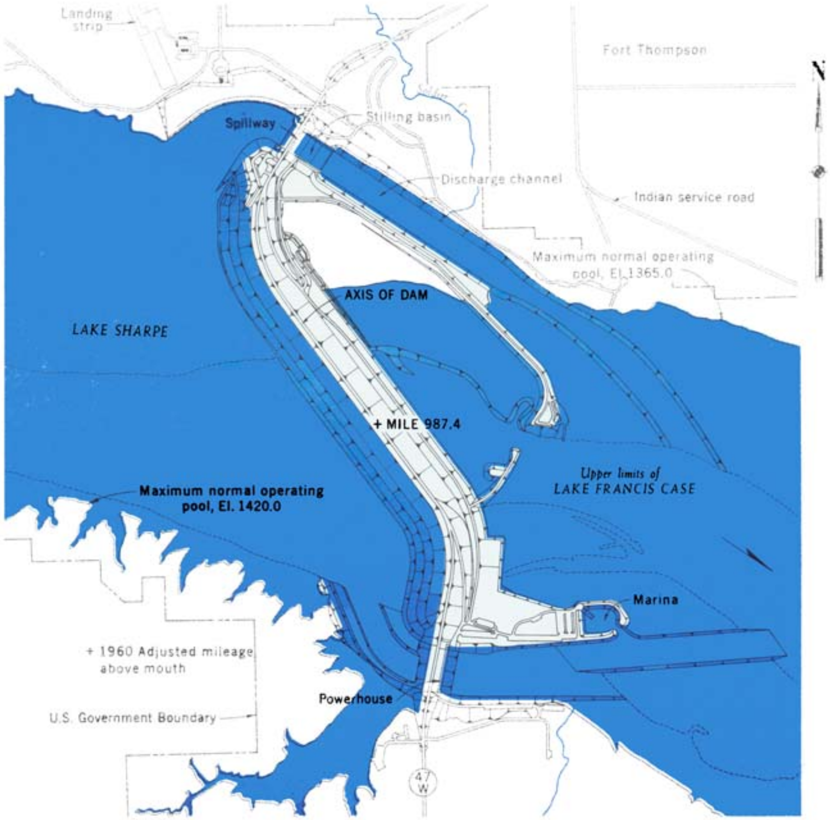


U.S. Army Corps of Engineers

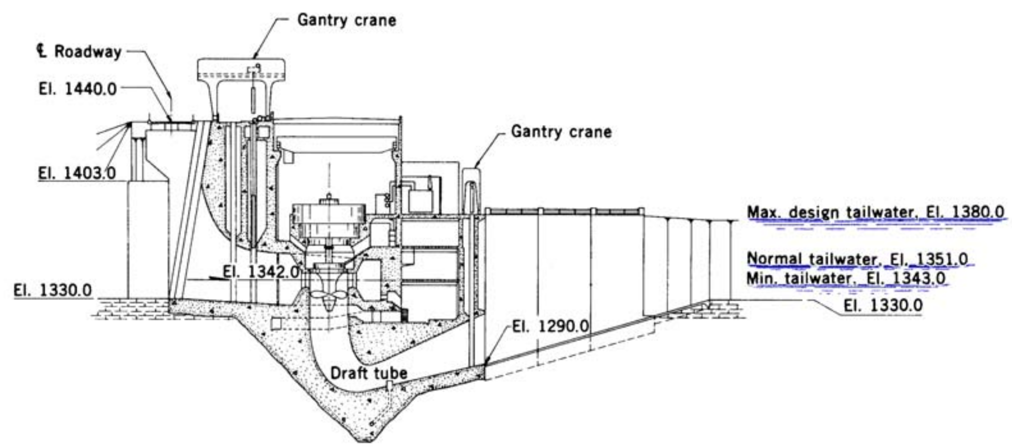
BIG BEND DAM
LAKE SHARPE
MISSOURI RIVER BASIN
SOUTH DAKOTA

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS
OMAHA, NEBRASKA
MARCH 2004

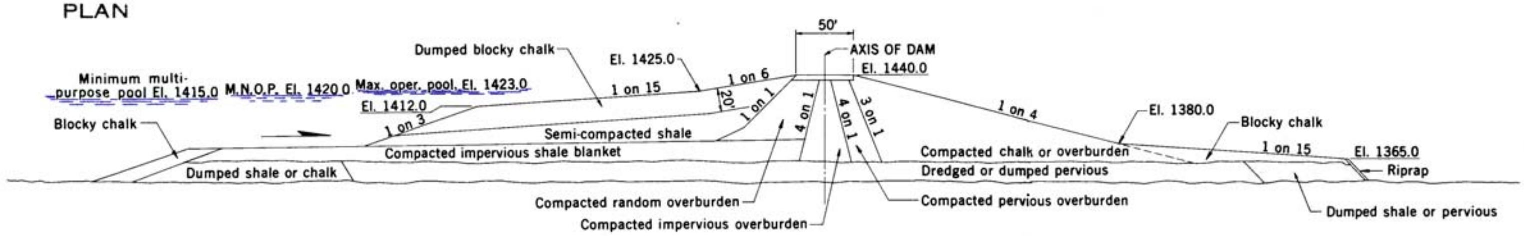
Plate II-45



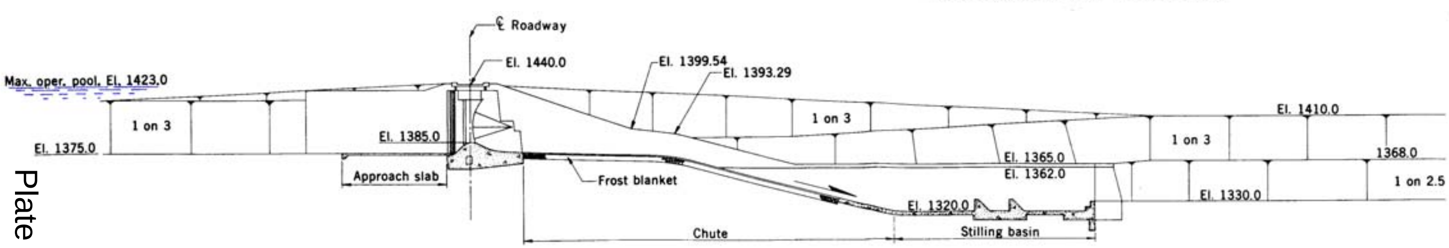
PLAN



POWERHOUSE SECTION



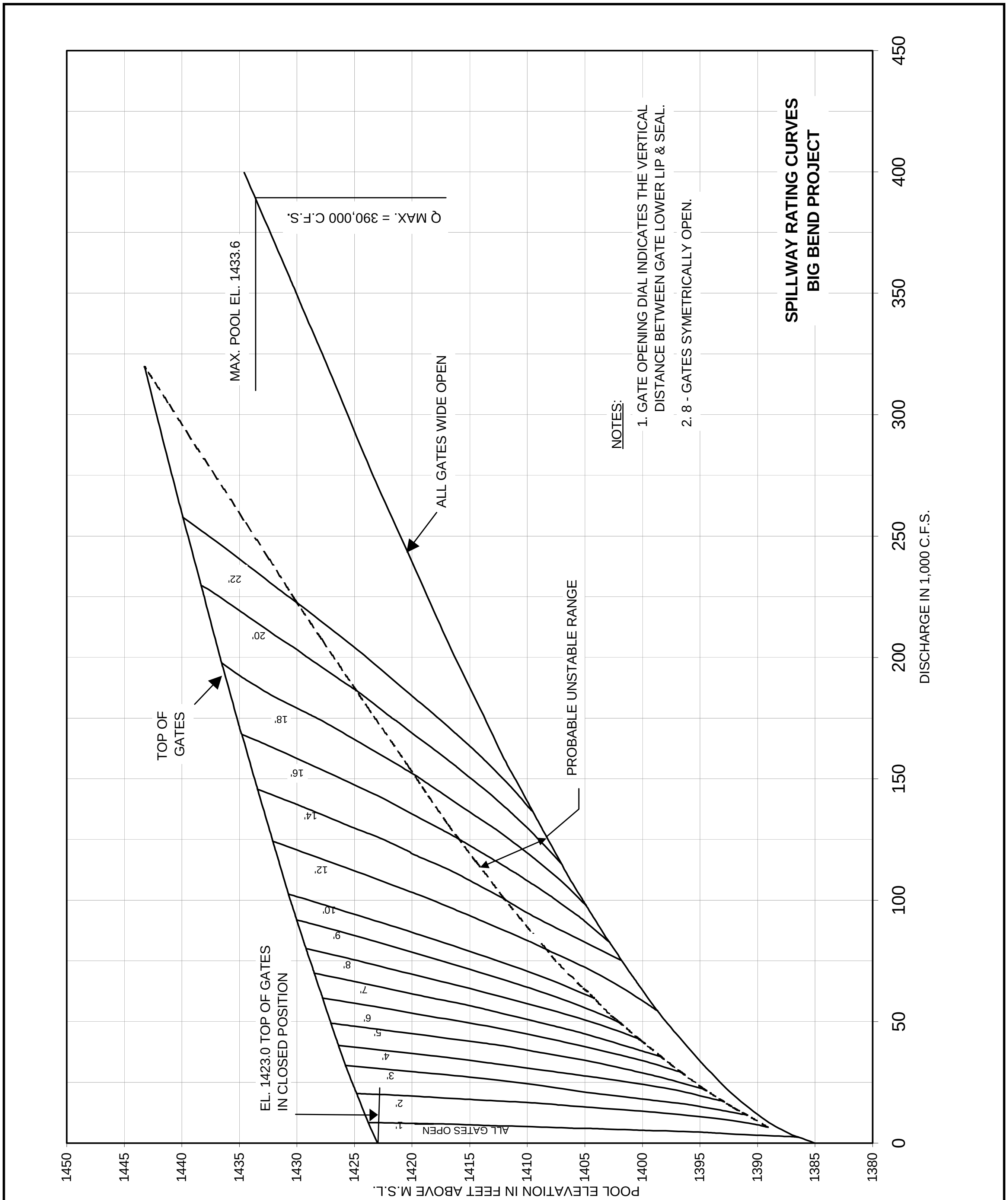
EMBANKMENT SECTION



SPILLWAY PROFILE

Missouri River Basin
Big Bend Dam
Lake Sharpe
Flood Control Project

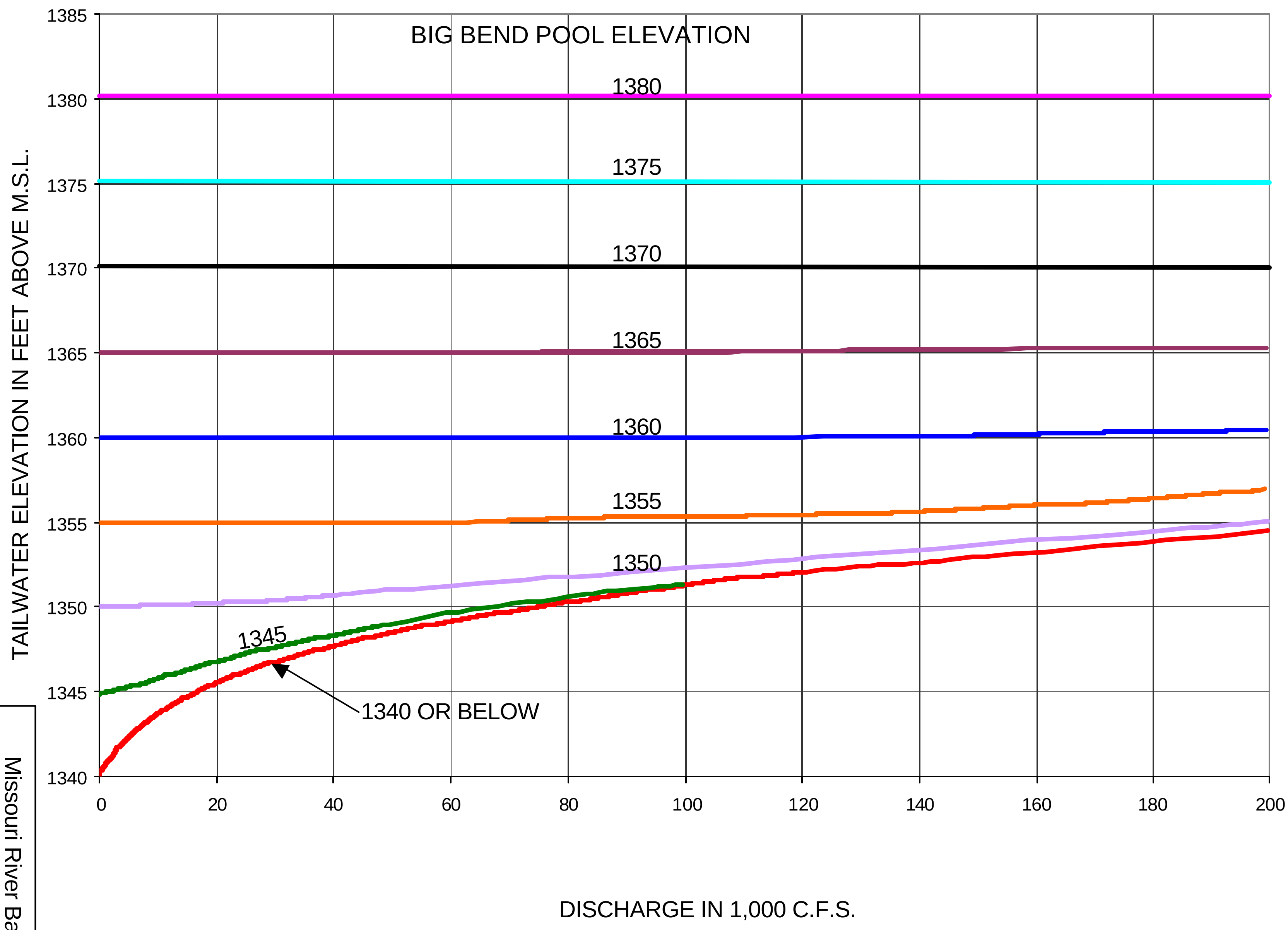
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
Spillway Rating Curves
Big Bend Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-47

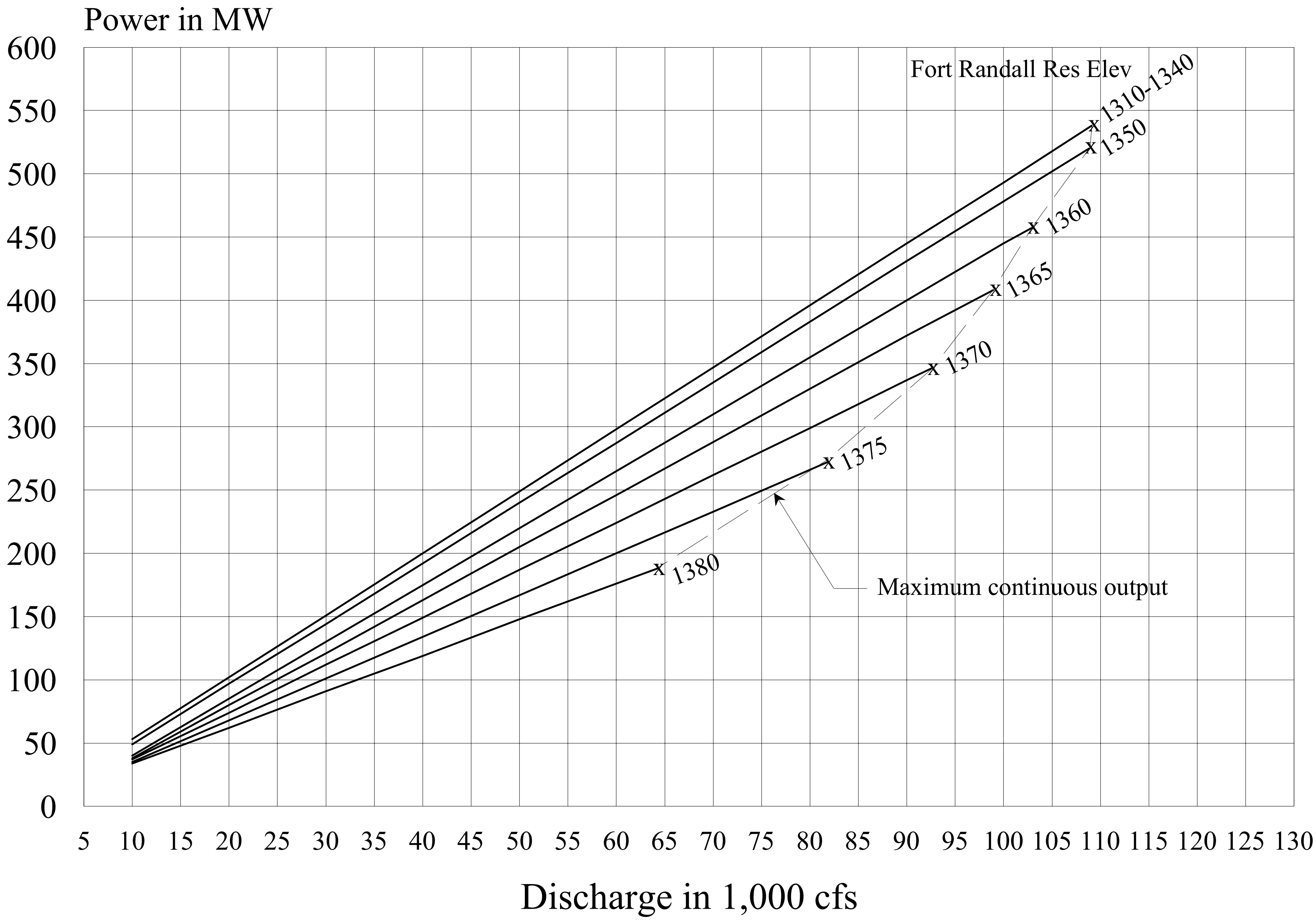


Missouri River Basin
Tailwater Rating Curves
Big Bend Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003

Plate II-48

Big Bend Powerplant



Missouri River Basin
Big Bend Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Area in Acres
(1997 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1340	0	0	0	119	226	273	320	368	415	462
1350	836	1181	1225	1380	1645	2021	2506	3103	3810	4627
1360	5449	6138	6744	7354	7970	8590	9215	9844	10479	11118
1370	11747	12353	12957	13576	14209	14856	15516	16192	16881	17585
1380	18307	19038	19757	20454	21128	21779	22407	23013	23597	24158
1390	24659	25096	25556	26093	26709	27402	28172	29020	29946	30950
1400	31842	32459	33031	33761	34649	35694	36897	38258	39776	41452
1410	43146	44666	46067	47460	48846	50224	51594	52957	54312	55660
1420	57007	58362	59724	61085	62447	63808	65169	66531	67893	69254
1430	70615									

Capacity in Acre-Feet
(1997 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1340	0	0	0	35	238	488	758	1129	1521	1959
1350	2445	3631	4807	6082	7567	9373	11609	14386	17815	22066
1360	27069	32905	39345	46393	54054	62333	71235	80763	90924	101721
1370	113160	125215	137867	151130	165019	179548	194731	210581	227115	244344
1380	262285	280958	300362	320473	341270	362729	384828	407544	430855	454739
1390	479182	504057	529364	555169	581551	608587	636355	664932	694396	724825
1400	756297	788510	821216	854573	888739	923872	960128	997666	1036644	1077219
1410	1119548	1163512	1204881	1255647	1303802	1353339	1404250	1456528	1510164	1565152
1420	1621484	1679166	1738209	1798614	1860380	1923508	1987997	2053847	2121059	2189633
1430	2259568									

Missouri River Basin
Big Bend Area-Capacity Tables

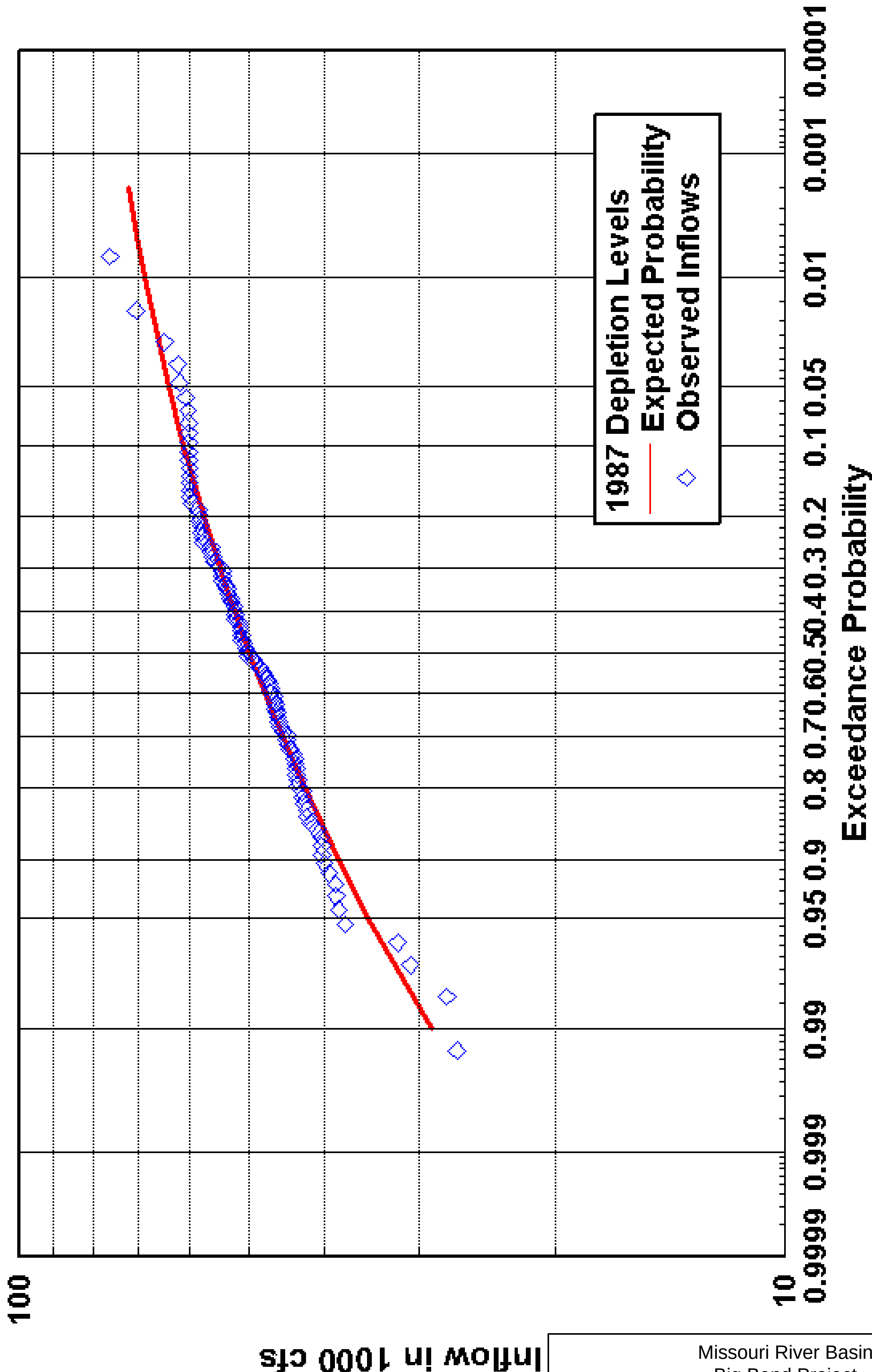
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-50

Missouri River Basin
Big Bend Project
Embankment, Reservoir,
Spillway, and Powerhouse

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

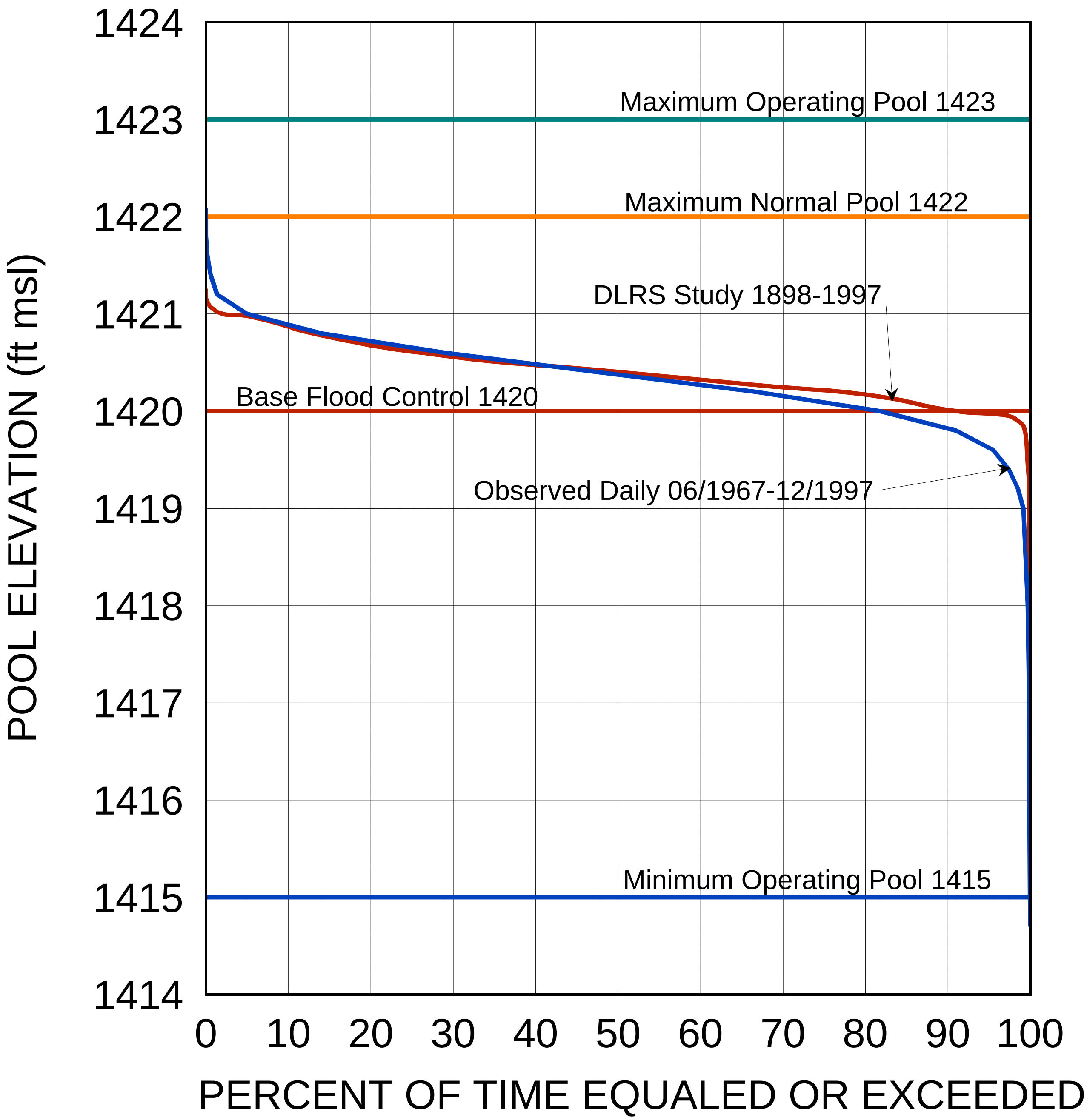
Plate II-51



Missouri River Basin
Big Bend Project
Inflow Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

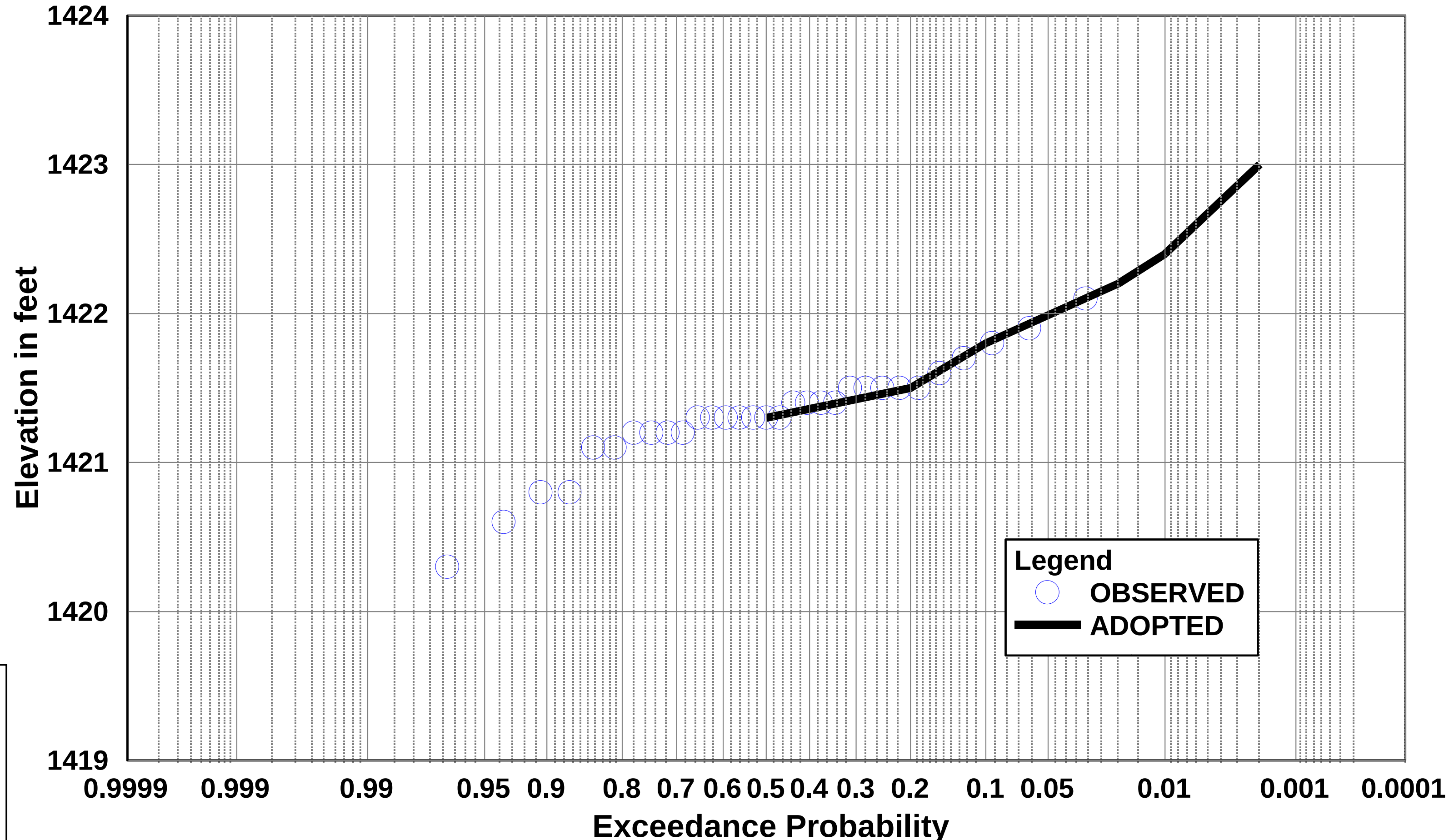
LAKE SHARPE

POOL DURATION RELATIONSHIP



Missouri River Basin
Big Bend Dam Pool Elevation Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
MARCH 2004

BIG BEND (LAKE SHARPE)
POOL-PROBABILITY RELATIONSHIP



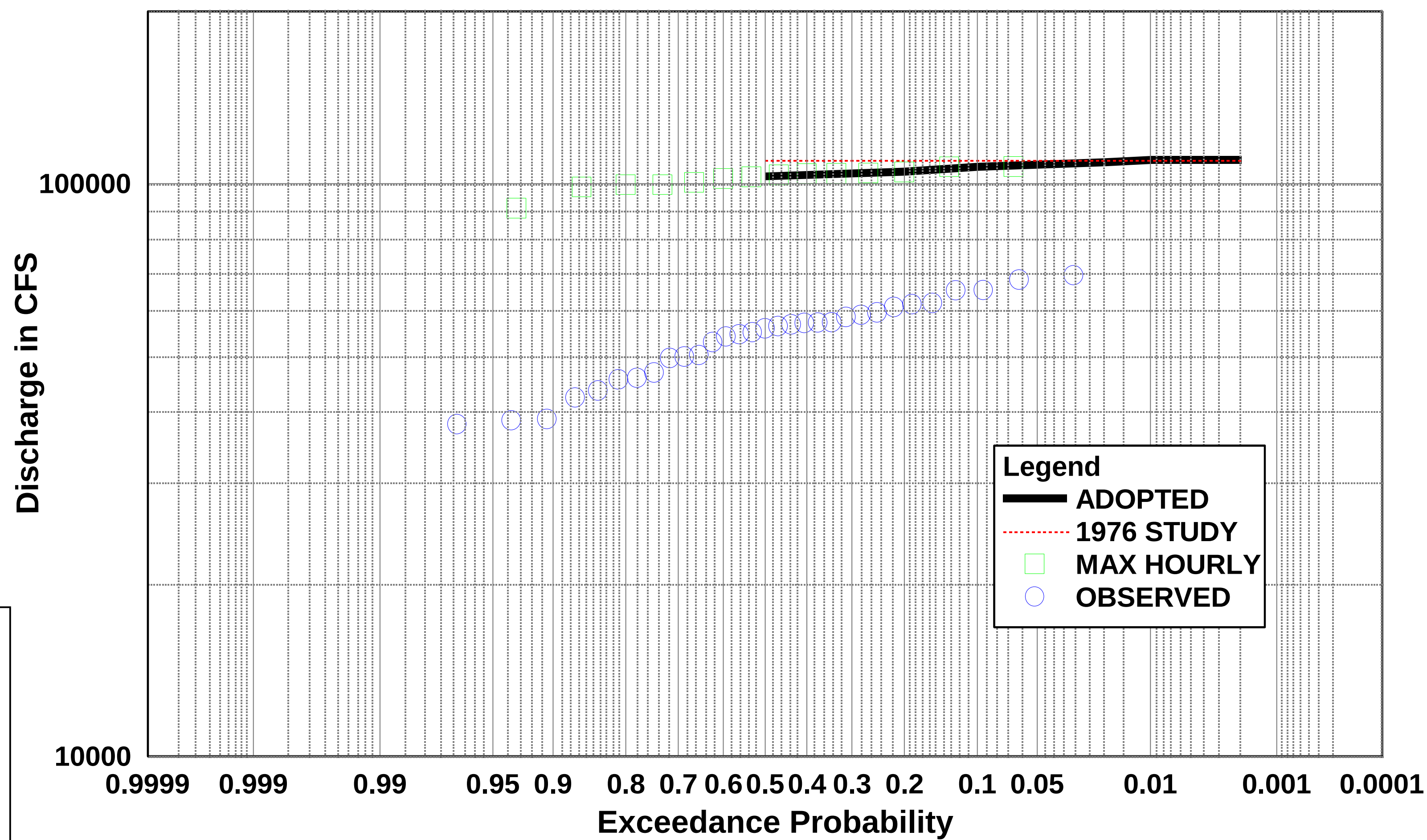
MAX POOL ELEVATION	=	1433.6
MAX OP. POOL ELEV	=	1423.0
MAX NORMAL POOL ELEV	=	1422.0
BASE FLOOD CONTROL	=	1420.0

Missouri River Basin
Big Bend Project
Pool-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-54

BIG BEND (LAKE SHARPE)
RELEASE-PROBABILITY RELATIONSHIP

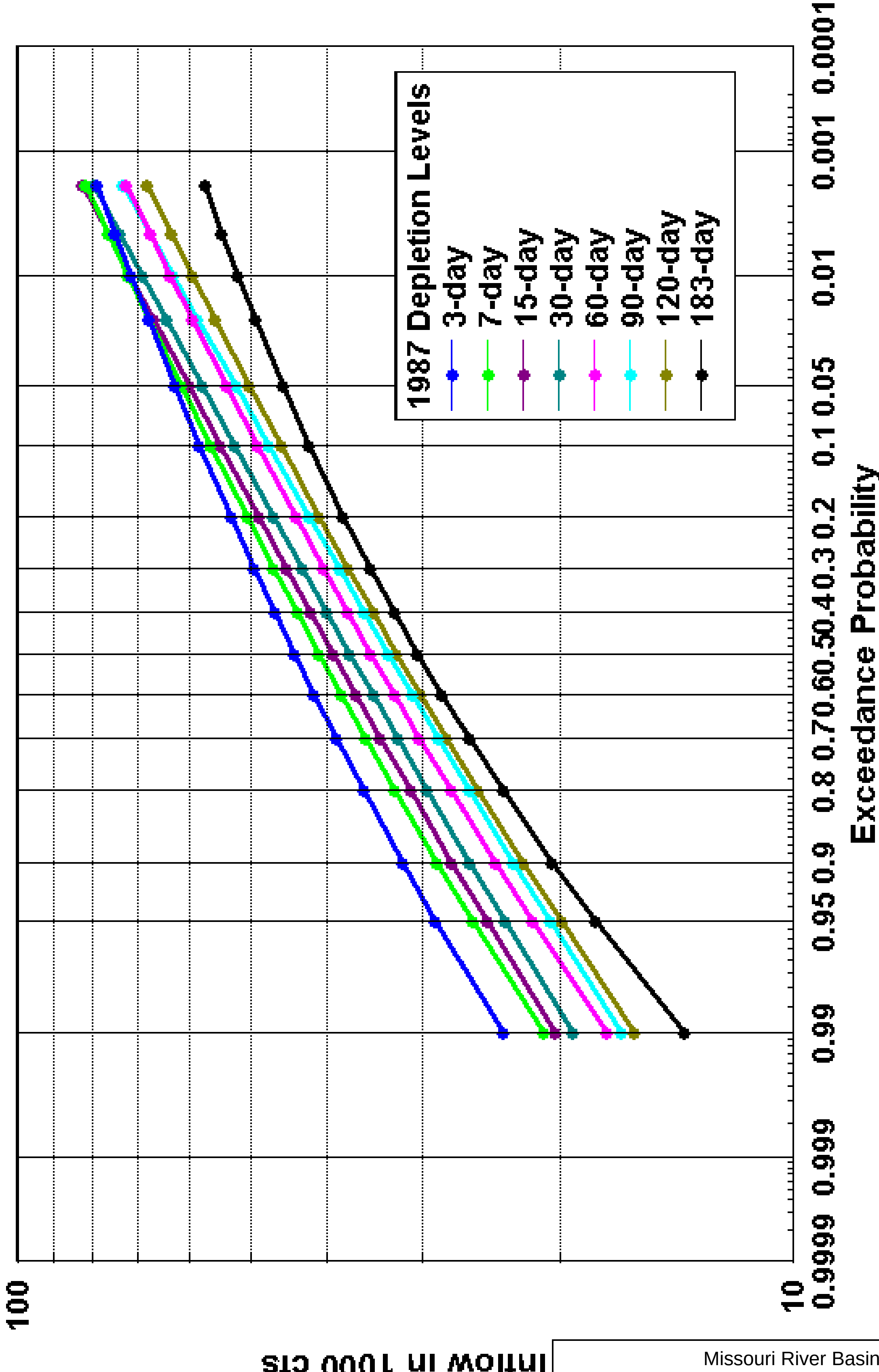


POWER PLANT CAPACITY = 103,000
OUTLET CAPACITY = 0
SPILLWAY CAPACITY = 390,000

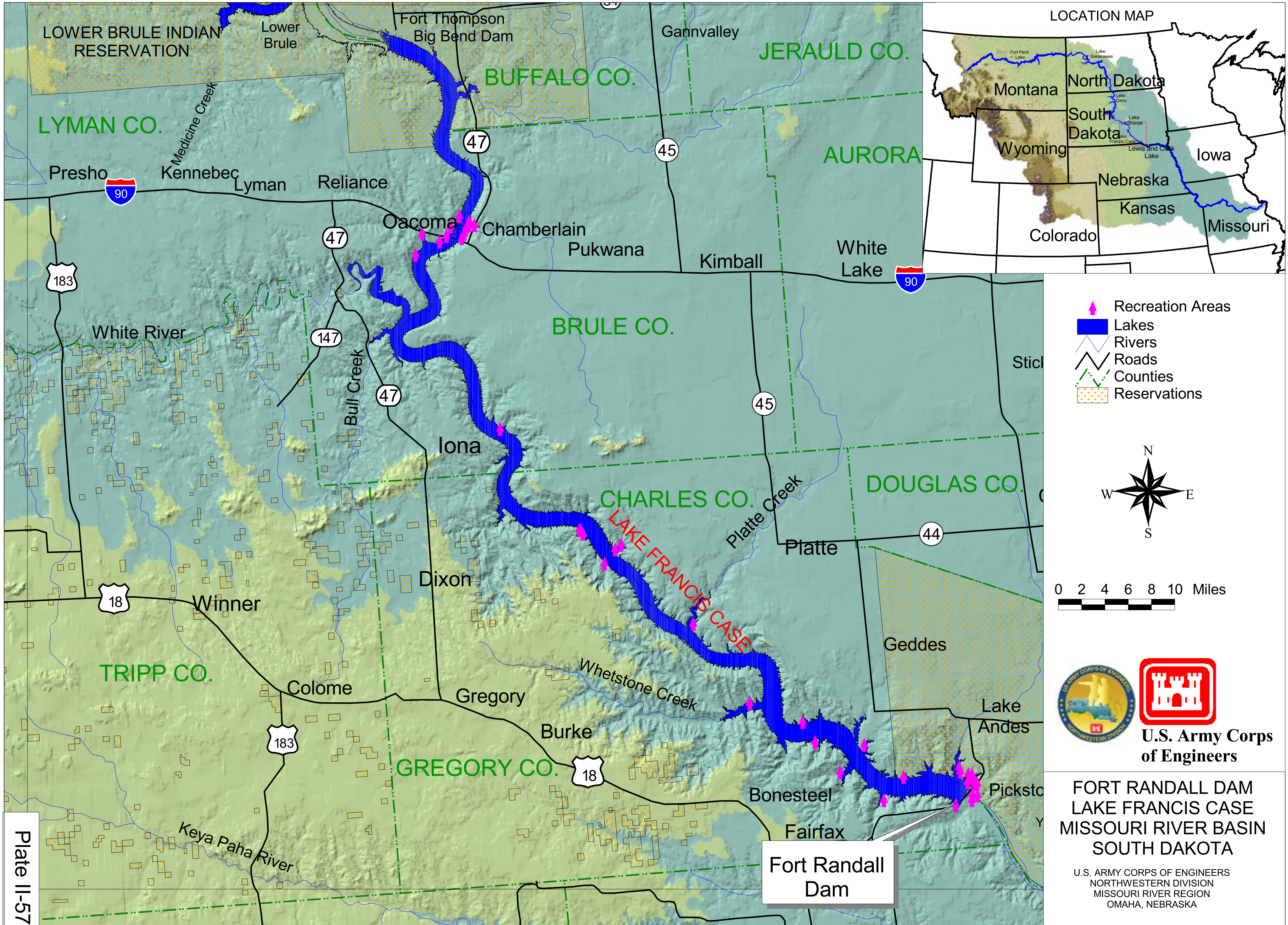
Missouri River Basin
Big Bend Project
Release-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-55

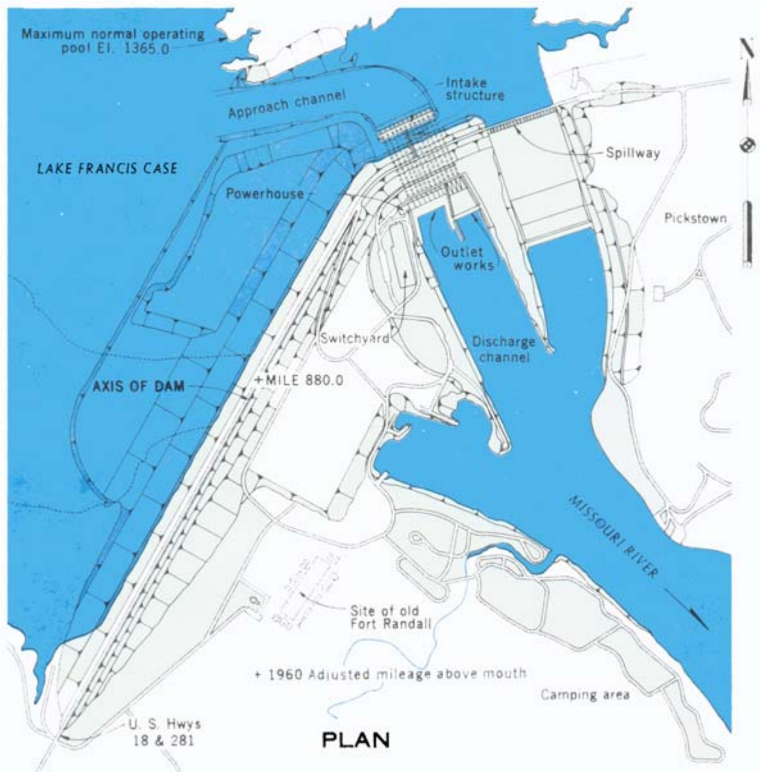


Missouri River Basin
Big Bend Project
Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

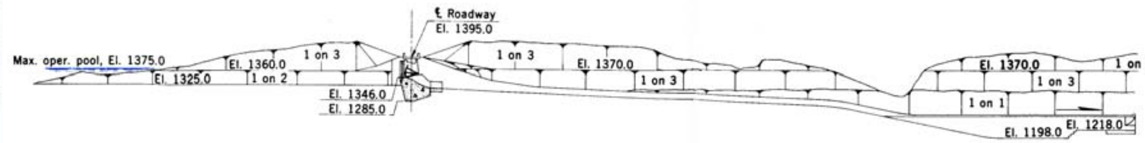


FORT RANDALL DAM
LAKE FRANCIS CASE
MISSOURI RIVER BASIN
SOUTH DAKOTA

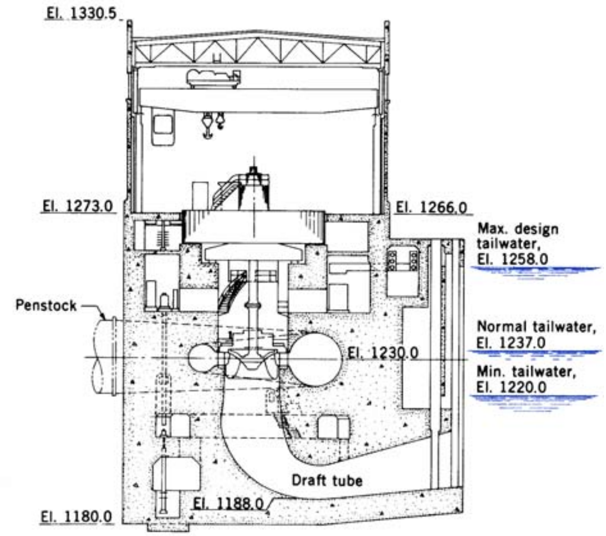
U.S. ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA



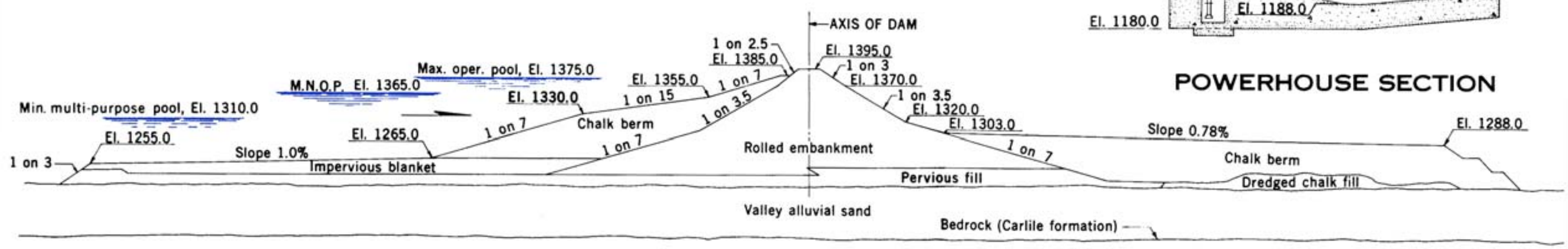
PLAN



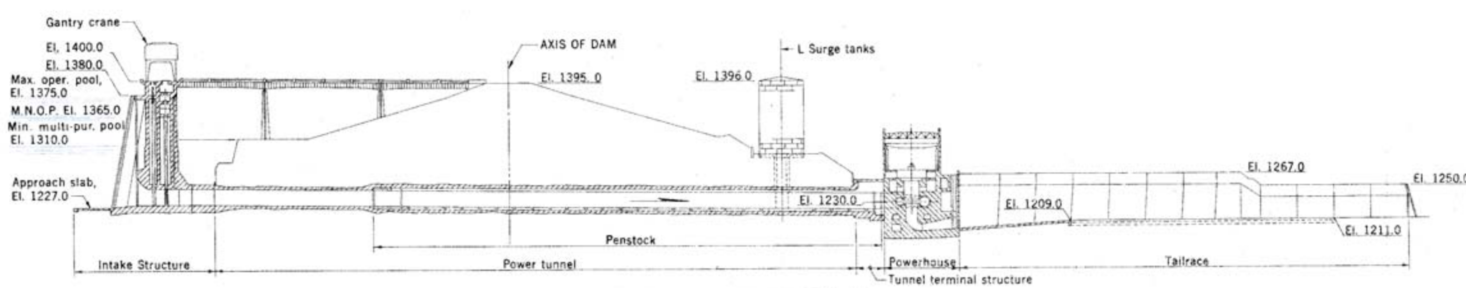
SPILLWAY PROFILE



POWERHOUSE SECTION



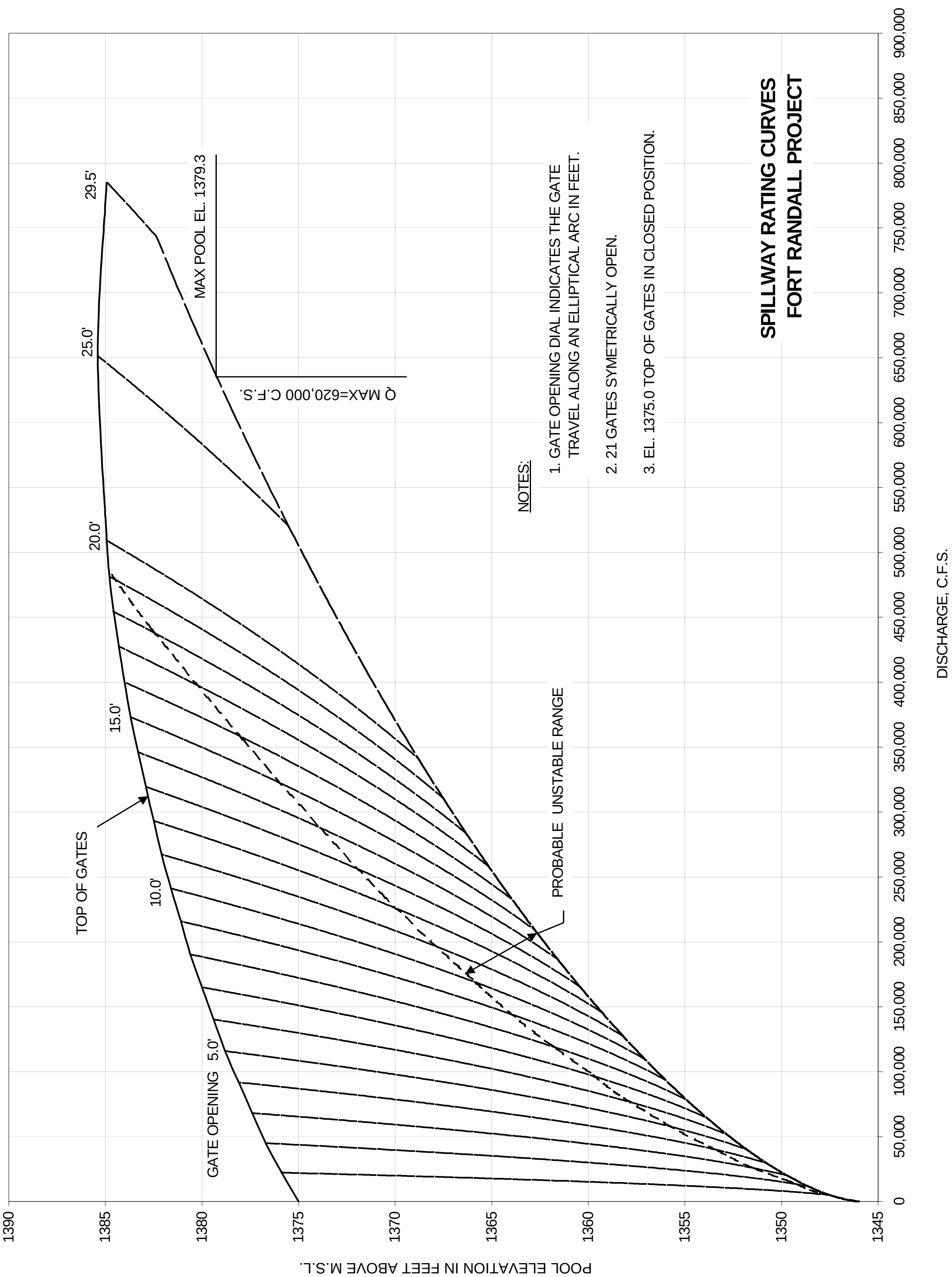
EMBANKMENT SECTION



OUTLET WORKS PROFILE

Missouri River Basin
Fort Randall Dam
Lake Francis Case
Flood Control Project

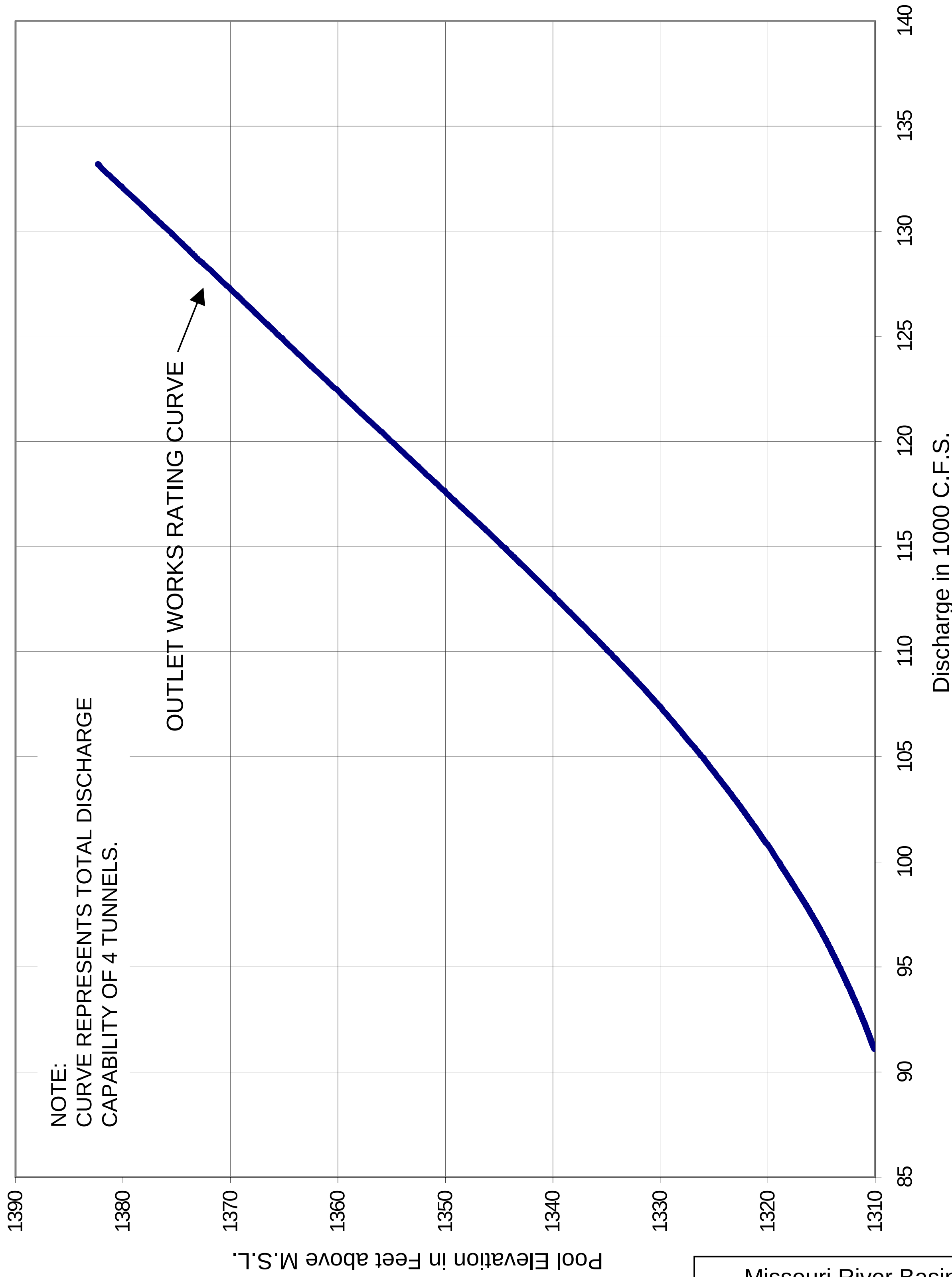
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
Spillway Rating Curves
Fort Randall Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

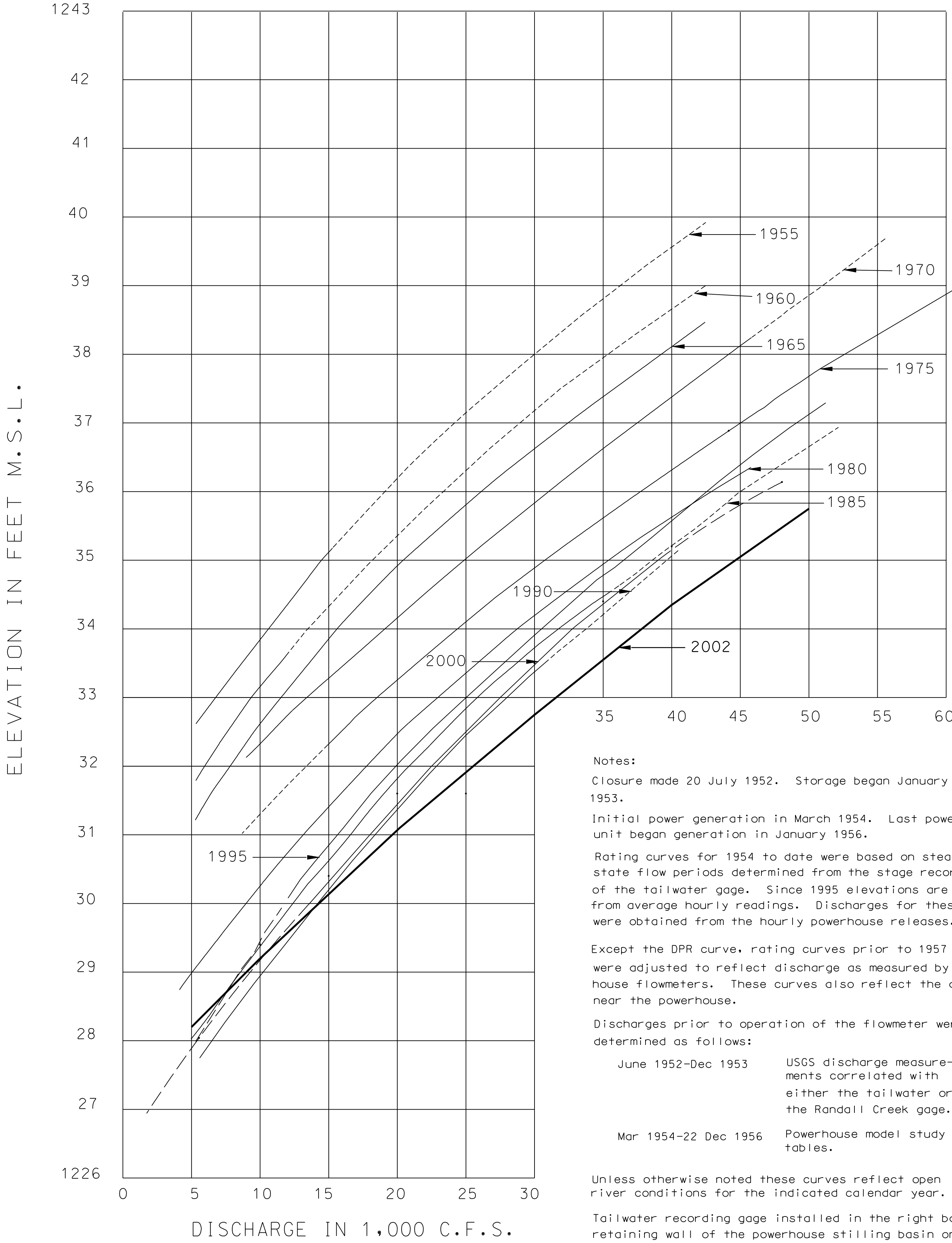
Plate II-59



Missouri River Basin
Outlet Works Rating Curve
Fort Randall Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEER
S, OMAHA, NEBRASKA
March 2004

Plate II-60



Notes:

Closure made 20 July 1952. Storage began January 1953.

Initial power generation in March 1954. Last power unit began generation in January 1956.

Rating curves for 1954 to date were based on steady state flow periods determined from the stage recorder charts of the tailwater gage. Since 1995 elevations are obtained from average hourly readings. Discharges for these periods were obtained from the hourly powerhouse releases.

Except the DPR curve, rating curves prior to 1957 were adjusted to reflect discharge as measured by the powerhouse flowmeters. These curves also reflect the drawdown near the powerhouse.

Discharges prior to operation of the flowmeter were determined as follows:

June 1952-Dec 1953	USGS discharge measurements correlated with either the tailwater or the Randall Creek gage.
Mar 1954-22 Dec 1956	Powerhouse model study tables.

Unless otherwise noted these curves reflect open river conditions for the indicated calendar year.

Tailwater recording gage installed in the right bank retaining wall of the powerhouse stilling basin on 9 July 1952.

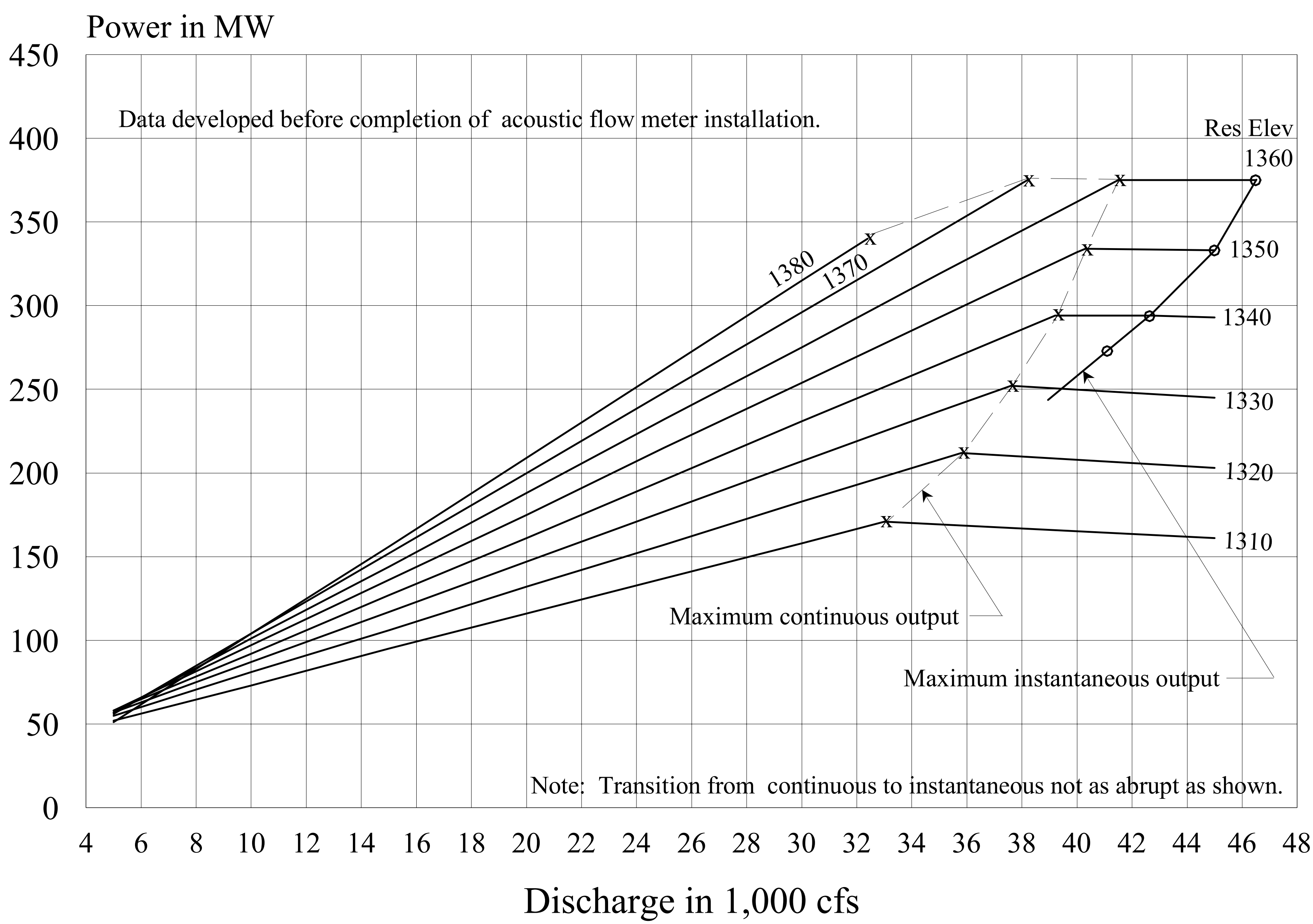
Missouri River Basin
Fort Randall
Tailwater Rating Curves

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS OMAHA, NEBRASKA
November 2003

Plate II-61

* 1995 curve shows an adjustment made to the datum. Not an aggradation trend. See trend plot.

Fort Randall Powerplant



Missouri River Basin
Fort Randall Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Area in Acres
(1996 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1240	0	0	0	0	347	586	713	840	967	1095
1250	1737	2452	2760	3136	3581	4093	4674	5323	6040	6825
1260	7637	8404	9117	9802	10457	11083	11680	12249	12788	13299
1270	13779	14248	14743	15275	15845	16452	17097	17780	18499	19257
1280	20061	20889	21684	22421	23100	23721	24284	24790	25237	25627
1290	26042	26571	27140	27669	28159	28608	29016	29385	29714	30003
1300	30297	30653	31038	31410	31770	32119	32454	32777	33089	33388
1310	33632	33809	34000	34262	34595	35000	35475	36022	36639	37327
1320	37911	38240	38529	38965	39547	40277	41153	42177	43347	44665
1330	45845	46621	47303	48185	49266	50547	52027	43708	5587	57666
1340	59783	61698	63462	65198	66907	68588	70242	71867	73465	75036
1350	76747	78713	80684	82465	84054	85453	86661	87677	88504	89140
1360	89808	90774	91878	92917	93891	94801	95647	86428	97144	97795
1370	98438	99150	99911	100676	101447	102224	103005	103791	104582	105379
1380	106176	106967	107755	108542	109329	110116	110903	111691	112478	113265
1390	114052									

Capacity in Acre-Feet
(1996 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1240	0	0	0	0	173	695	1345	2121	3025	4056
1250	5215	7530	10119	13050	16392	20212	24579	29561	35225	41641
1260	48875	46915	65683	75150	85287	96065	107454	119426	131952	145003
1270	158550	172561	187047	202047	217598	233738	250503	267933	286063	304932
1280	324578	245055	366357	388424	411199	434624	458641	483193	508221	533668
1290	559475	585752	612617	640032	667956	696350	725172	754383	783943	813812
1300	843949	874407	905256	936483	968076	1000024	1032314	1064933	1097869	1131111
1310	1164645	1198376	1232263	1266377	1300788	1335568	1370788	1406519	1442832	1479797
1320	1517486	1555619	1593967	1632678	1671897	1711773	1752451	1794080	1836806	1880775
1330	1926136	1972466	2019378	2067073	2115749	2165606	2216843	2269661	2324259	2380835
1340	2439591	2500401	2562988	2627325	2693385	2751139	2830561	2901623	2974296	3048554
1350	3124368	3203049	3281795	3363418	3446725	3531526	3617631	3704848	3792986	3881856
1360	3971266	4061472	4152814	4245228	4338648	4433011	4528251	4324305	4721107	4818593
1370	4916698	5015469	5114999	5215291	5316352	5418186	5520800	5624197	5728382	5833362
1380	5939141	6045715	6153076	6261225	6370160	6479883	6590393	6701690	6813775	6926646
1390	7040305									

Missouri River Basin
Fort Randall Area-Capacity Tables

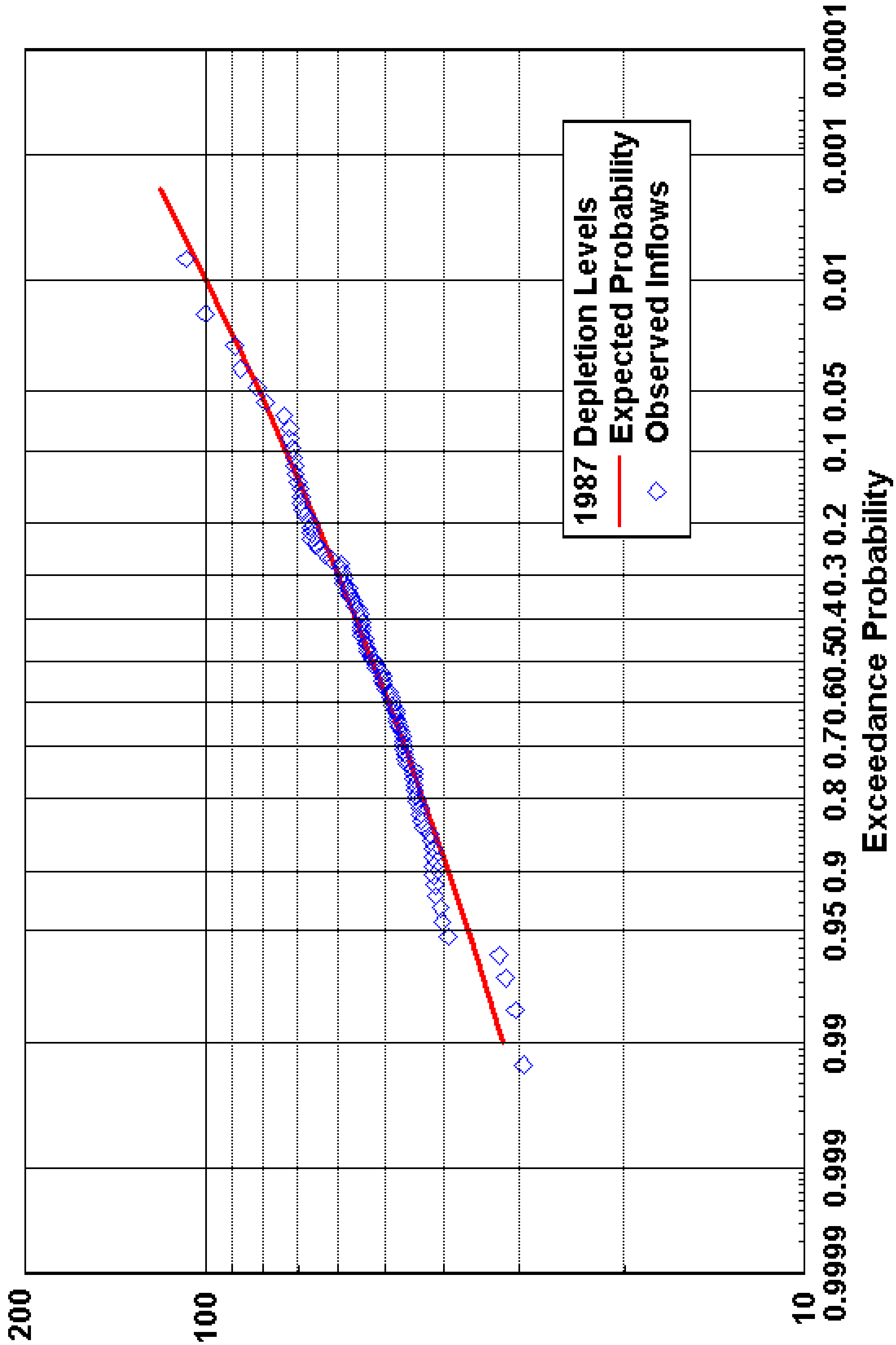
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-63

Missouri River Basin
Fort Randall Project
Embankment, Intakes,
Spillway, and Powerhouse

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

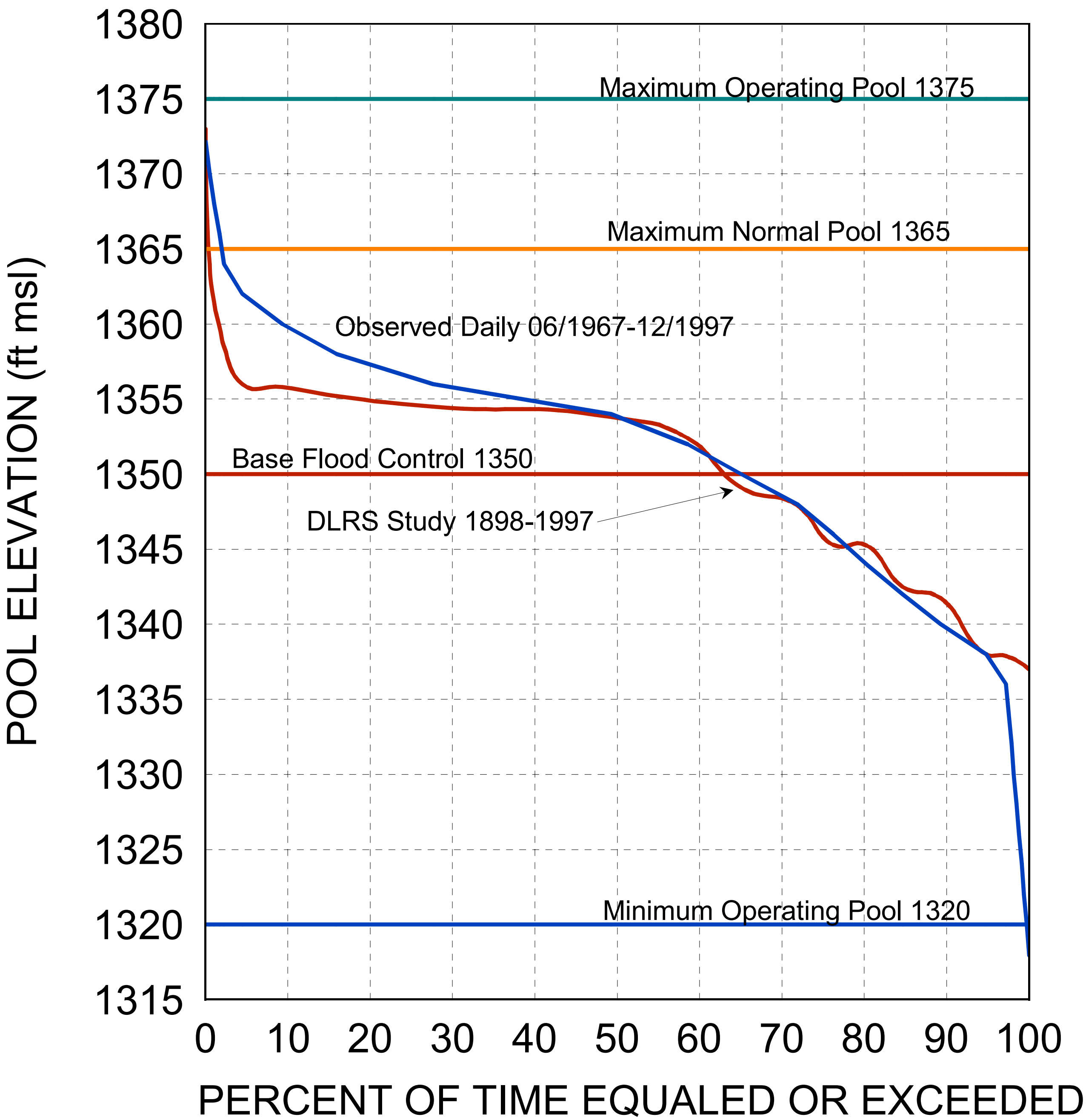
Plate II-64



Missouri River Basin
Fort Randall Project
Inflow Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

LAKE FRANCIS CASE

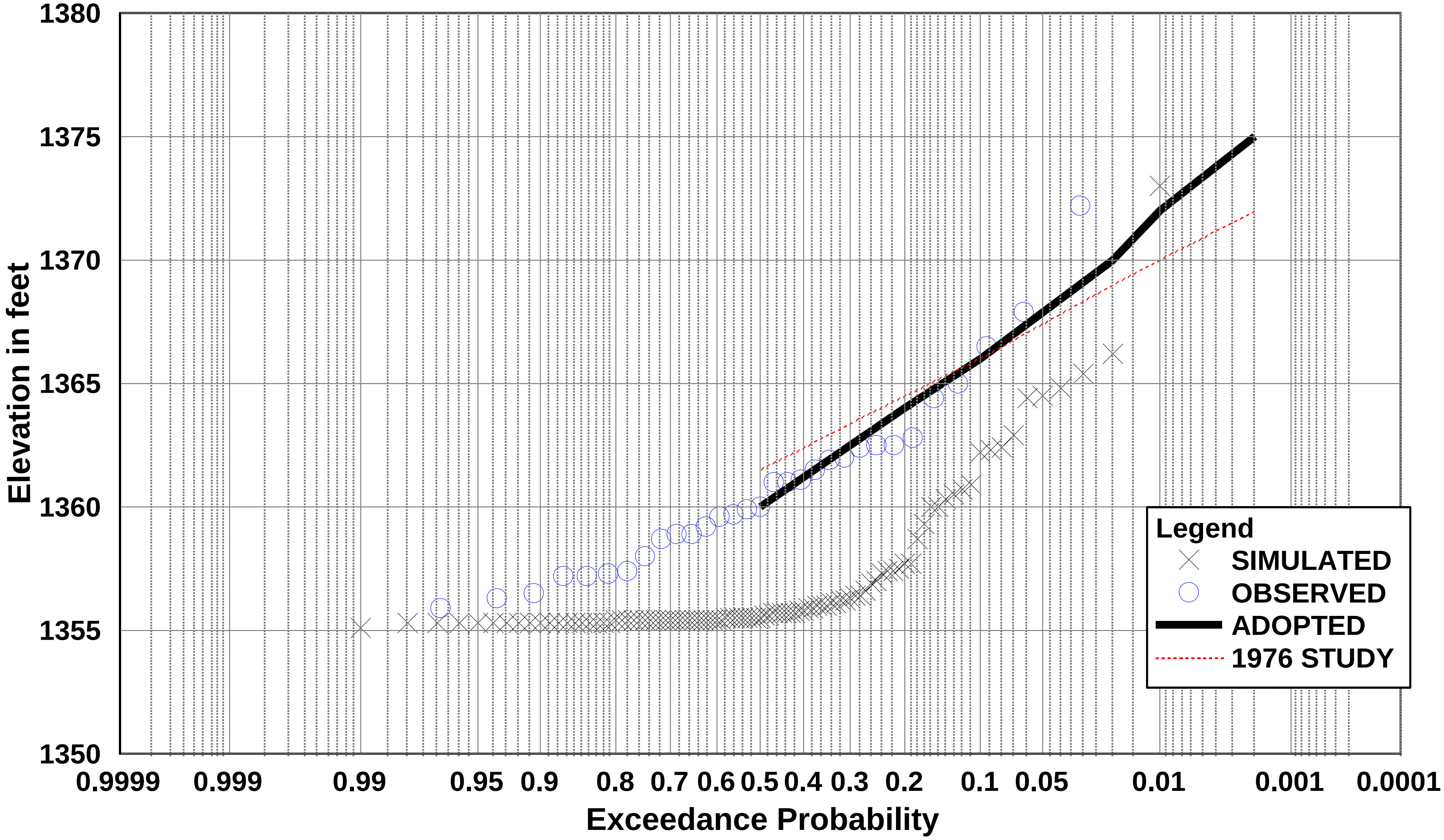
POOL DURATION RELATIONSHIP



Missouri River Basin
Fort Randall Dam Pool Elevation Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-66

FORT RANDALL (LAKE FRANCIS CASE)
POOL-PROBABILITY RELATIONSHIP



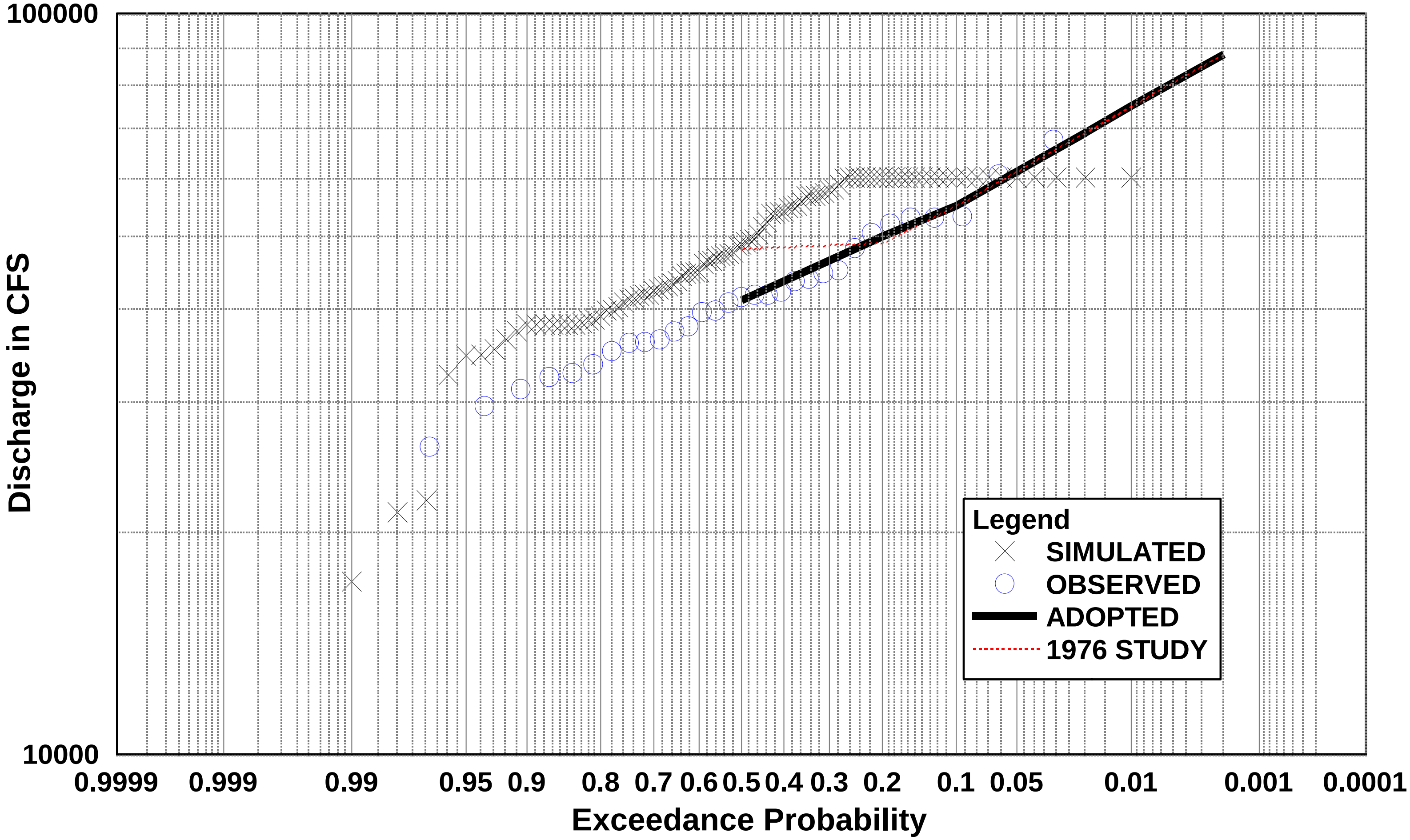
MAX POOL ELEVATION = 1379.3
MAX OP. POOL ELEV = 1375.0
MAX NORMAL POOL ELEV = 1365.0
BASE FLOOD CONTROL = 1350.0

Missouri River Basin
Fort Randall Project
Pool-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-67

FORT RANDALL (LAKE FRANCIS CASE)
RELEASE-PROBABILITY RELATIONSHIP

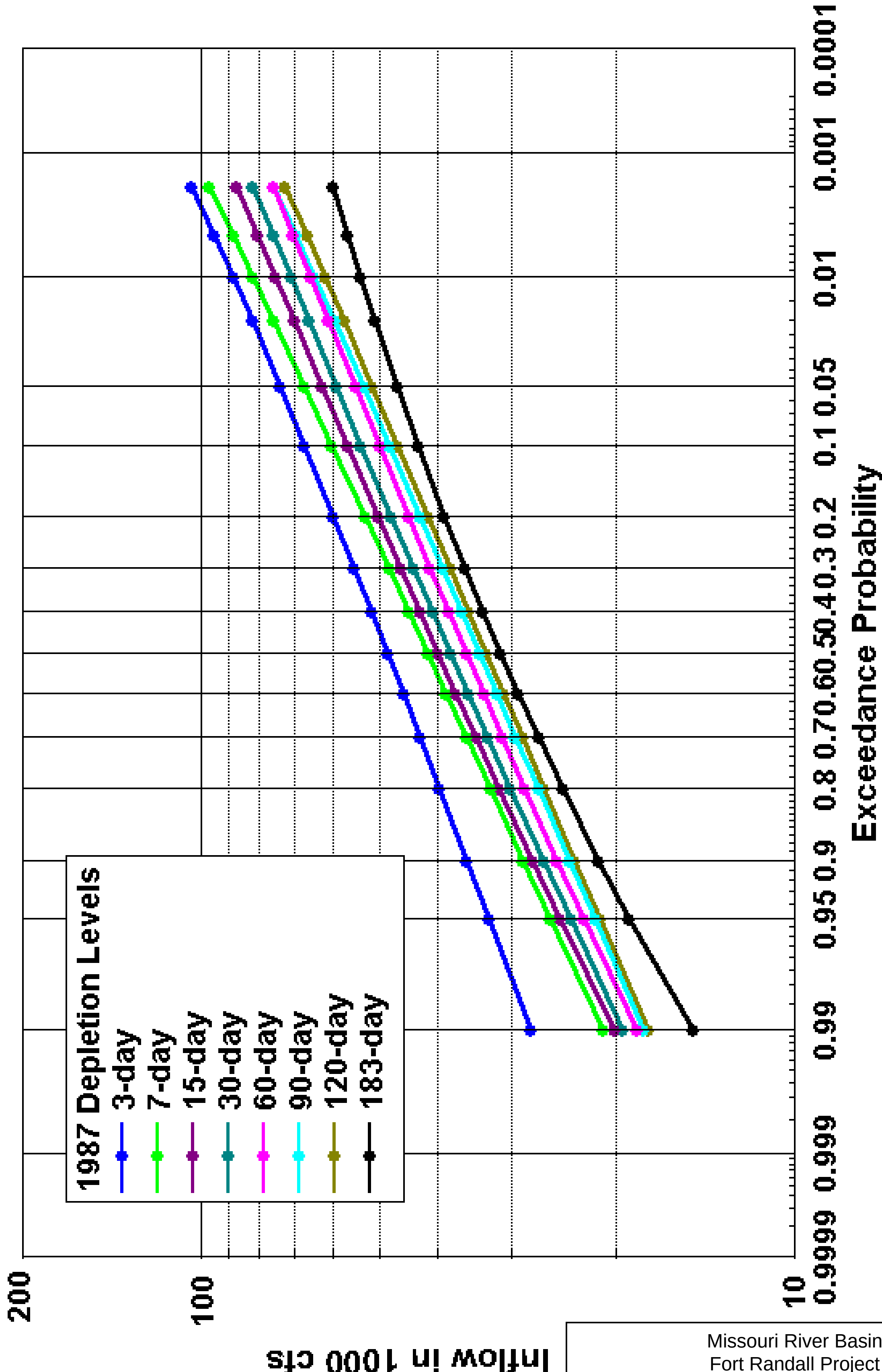


POWER PLANT CAPACITY = 44,500
OUTLET CAPACITY = 128,000
SPILLWAY CAPACITY = 620,000

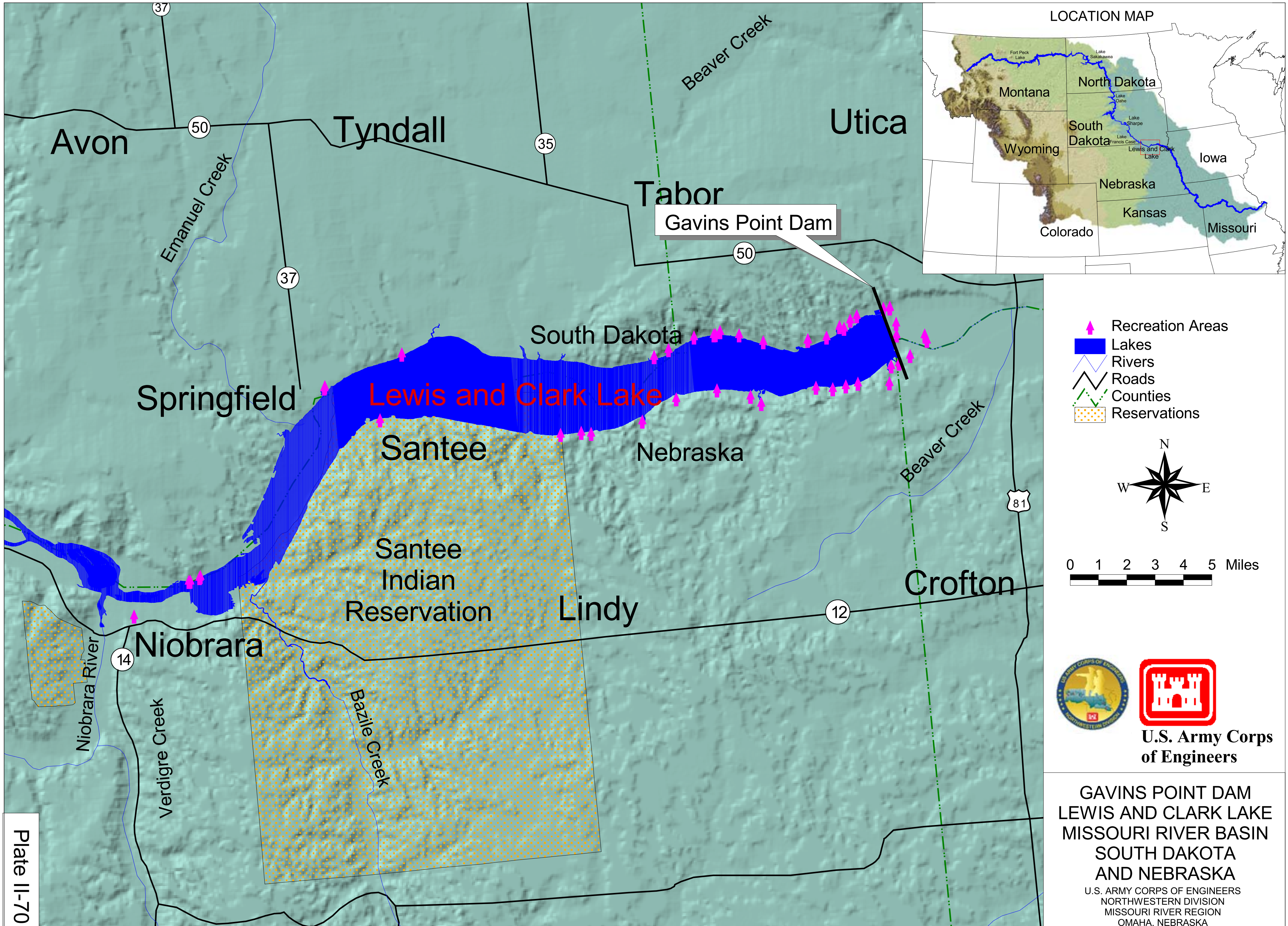
Missouri River Basin
Fort Randall Project
Release-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-68

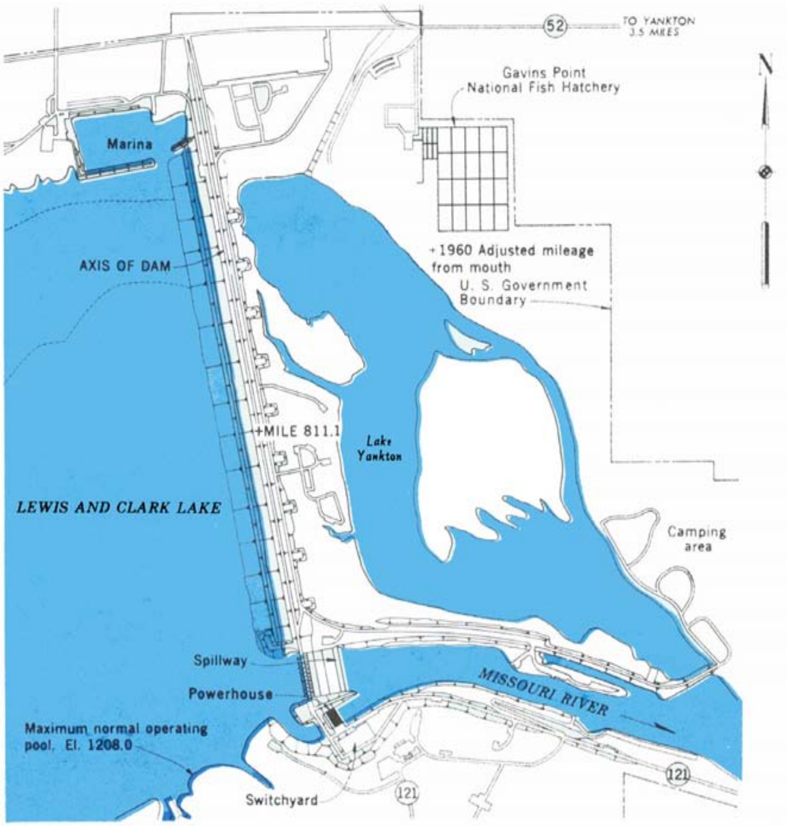


Missouri River Basin
Fort Randall Project
Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

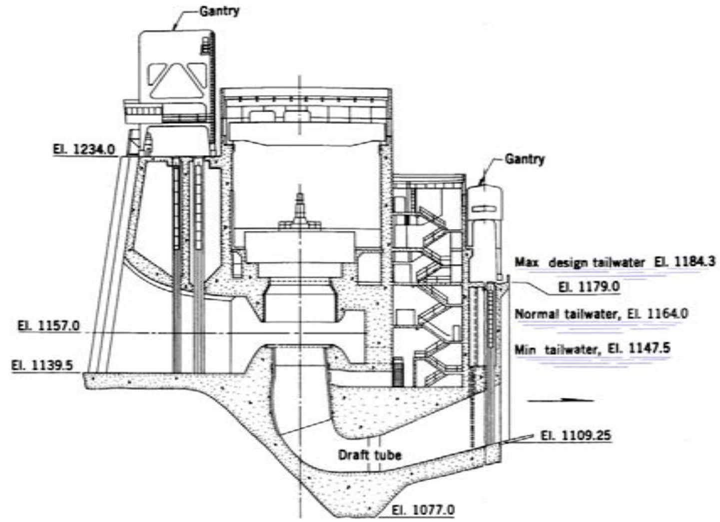


LOCATION MAP
Montana
North Dakota
South Dakota
Wyoming
Nebraska
Kansas
Colorado
Iowa
Missouri
Utica
Tyndall
Avon
Tabor
Gavins Point Dam
Springfield
Lewis and Clark Lake
South Dakota
Nebraska
Santee
Santee Indian Reservation
Lindy
Crofton
Niobrara
Beaver Creek
Emanuel Creek
Bazile Creek
Verdigre Creek
Niobrara River
Recreation Areas
Lakes
Rivers
Roads
Counties
Reservations
N
S
E
W
0 1 2 3 4 5 Miles
U.S. Army Corps of Engineers
GAVINS POINT DAM
LEWIS AND CLARK LAKE
MISSOURI RIVER BASIN
SOUTH DAKOTA
AND NEBRASKA
U.S. ARMY CORPS OF ENGINEERS
NORTHWESTERN DIVISION
MISSOURI RIVER REGION
OMAHA, NEBRASKA

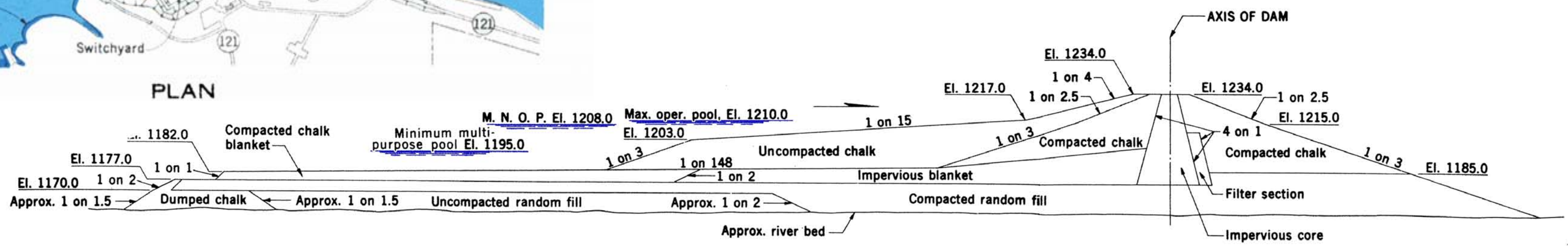
Plate II-70



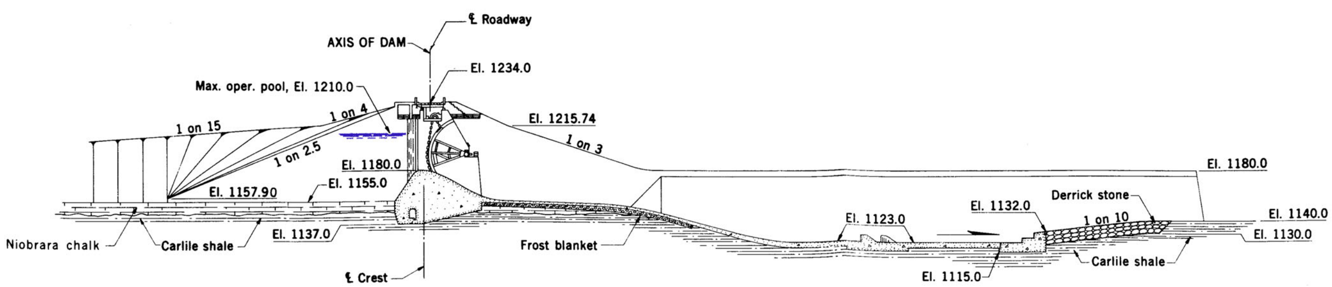
PLAN



POWERHOUSE SECTION



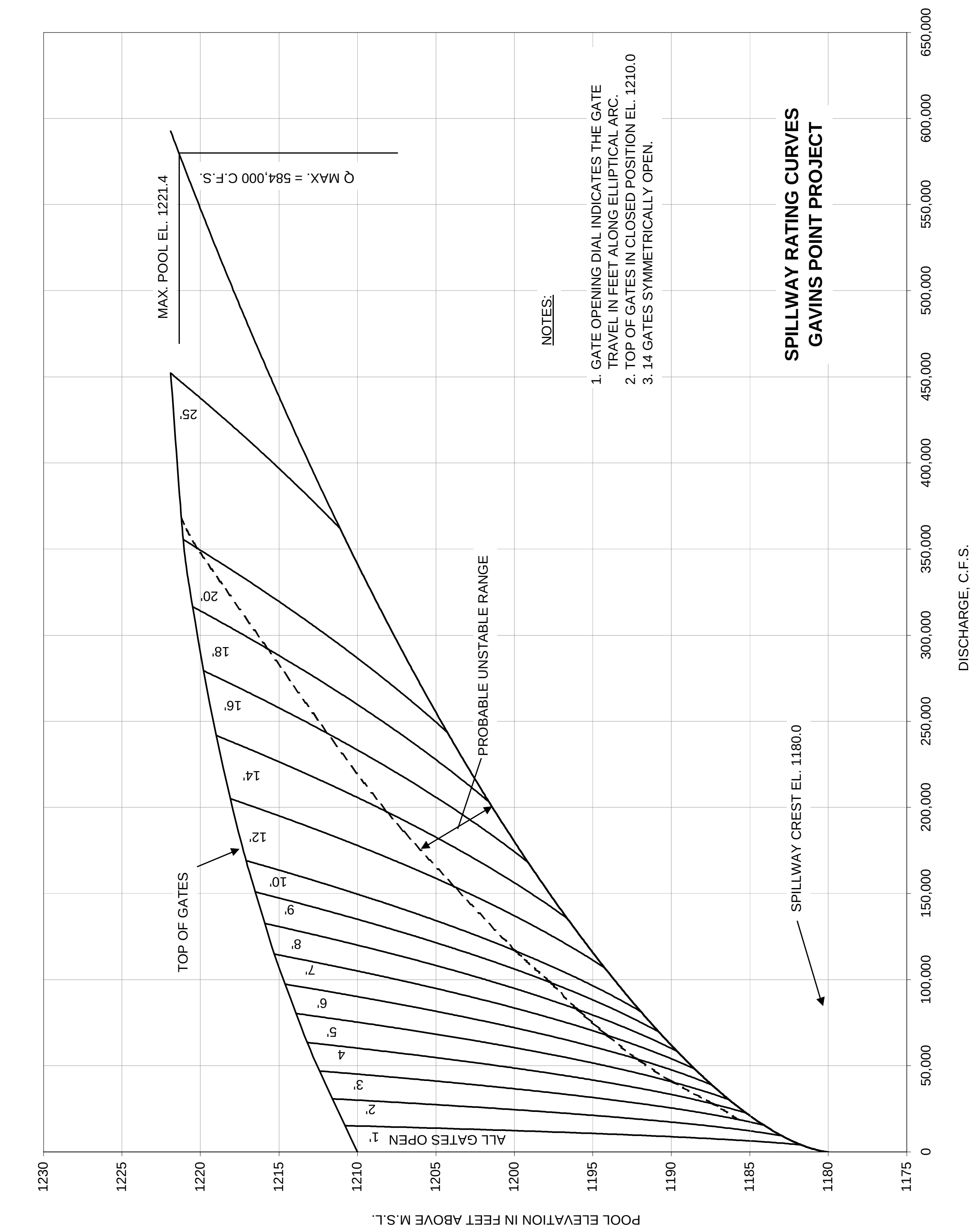
EMBANKMENT SECTION



SPILLWAY PROFILE

Missouri River Basin
Gavins Point Dam
Lewis and Clark Lake
Flood Control Project

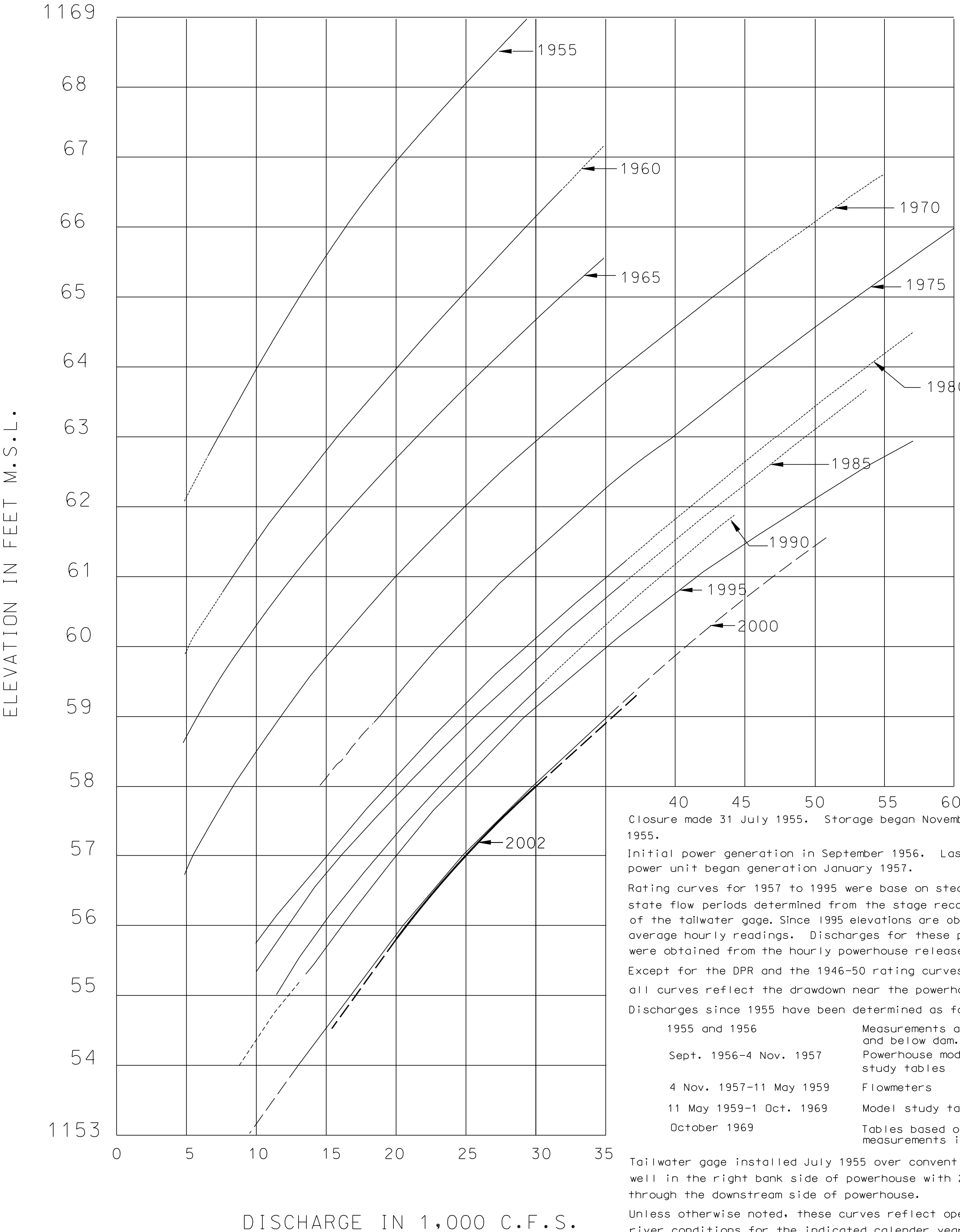
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
Spillway Rating Curves
Gavins Point Project

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-72



Closure made 31 July 1955. Storage began November 1955.

Initial power generation in September 1956. Last power unit began generation January 1957.

Rating curves for 1957 to 1995 were base on steady state flow periods determined from the stage recorder charts of the tailwater gage. Since 1995 elevations are obtained from average hourly readings. Discharges for these periods were obtained from the hourly powerhouse releases.

Except for the DPR and the 1946-50 rating curves, all curves reflect the drawdown near the powerhouse.

Discharges since 1955 have been determined as follows:

1955 and 1956	Measurements at Yankton and below dam.
Sept. 1956-4 Nov. 1957	Powerhouse model study tables
4 Nov. 1957-11 May 1959	Flowmeters
11 May 1959-1 Oct. 1969	Model study tables + 5%
October 1969	Tables based on prototype measurements in the intakes.

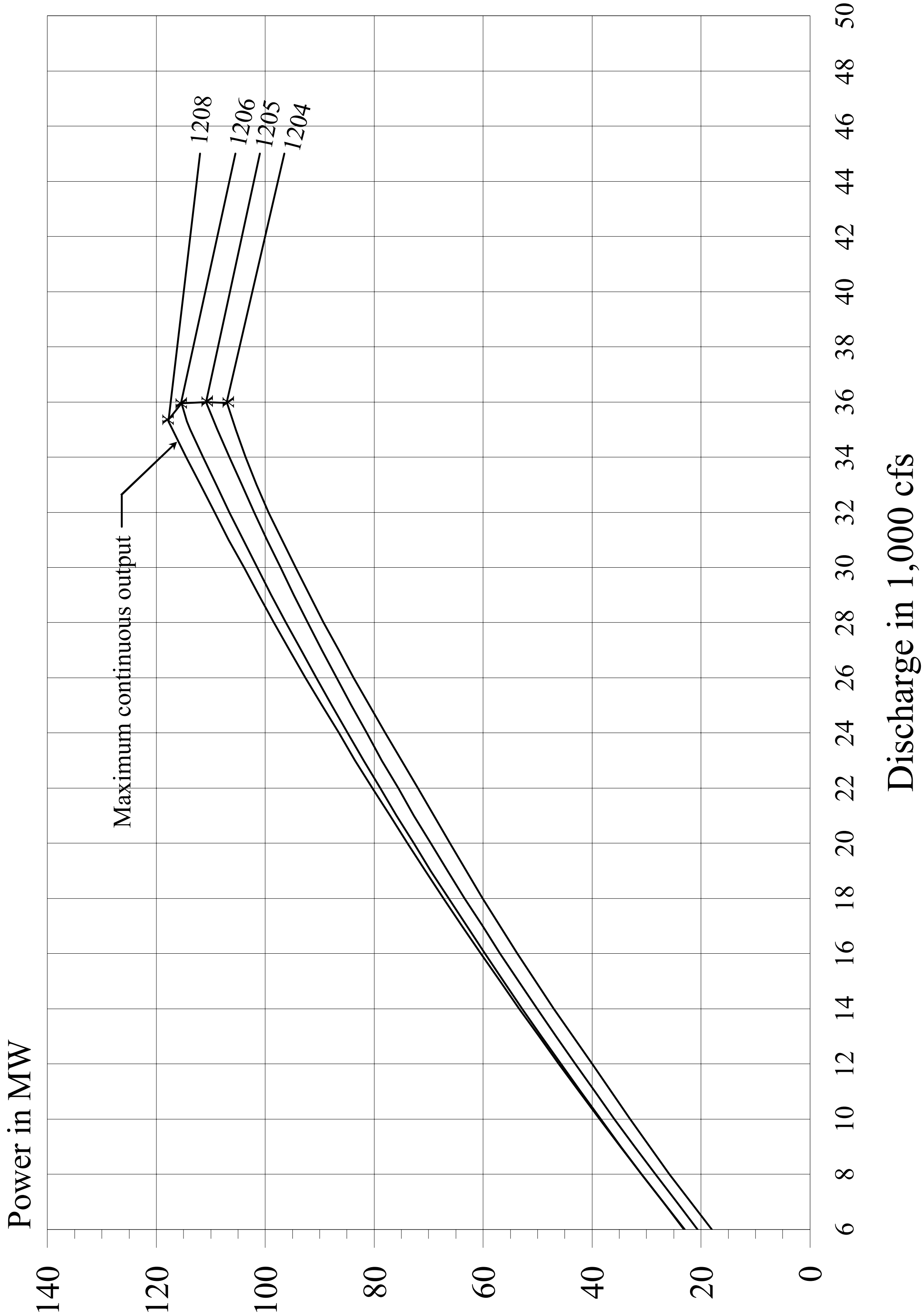
Tailwater gage installed July 1955 over conventional well in the right bank side of powerhouse with 2 intakes through the downstream side of powerhouse.

Unless otherwise noted, these curves reflect open river conditions for the indicated calender year.

Missouri River Basin
Gavins Point Project
Tailwater Rating Curves

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS OMAHA, NEBRASKA
November 2003
Plate II-73

Gavins Point Powerplant



Missouri River Basin
Gavins Point Powerplant Characteristics
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Area in Acres
(1995 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	0	0	0	117	195	247	299
1170	451	566	586	688	870	1133	1478	1903	2410	2997
1180	3486	3715	3895	4217	4679	5283	6028	6914	7941	9110
1190	10276	11257	12134	13029	13941	14871	15820	16787	17771	18773
1200	19713	20533	21345	22244	23228	24296	25451	26691	28015	29426
1210	30880	32290	33633	34928	36173	37370	38520	39620	40672	41677
1220	42677	43733	44825	45918	47010	48103	49196	50288	51381	52473
1230	56132									

Capacity in Acre-Feet
(1995 Survey)

ELEV	0	1	2	3	4	5	6	7	8	9
1160	0	0	0	0	0	0	65	234	455	728
1170	1053	1630	2186	2803	3562	4543	5829	7499	9636	12319
1180	15631	19292	23062	27083	31496	36442	42062	48498	55890	64381
1190	74110	84934	96625	109202	122683	173085	152426	168725	186000	204268
1200	223547	243695	264613	286386	309101	332842	357694	383744	411076	439775
1210	469928	501535	534509	568802	604365	641149	679106	718189	758347	799534
1220	841701	884888	929167	974539	1021003	1068560	1117210	1166952	1217787	1269714
1230	1322734									

Missouri River Basin
Gavins Point Area-Capacity Tables

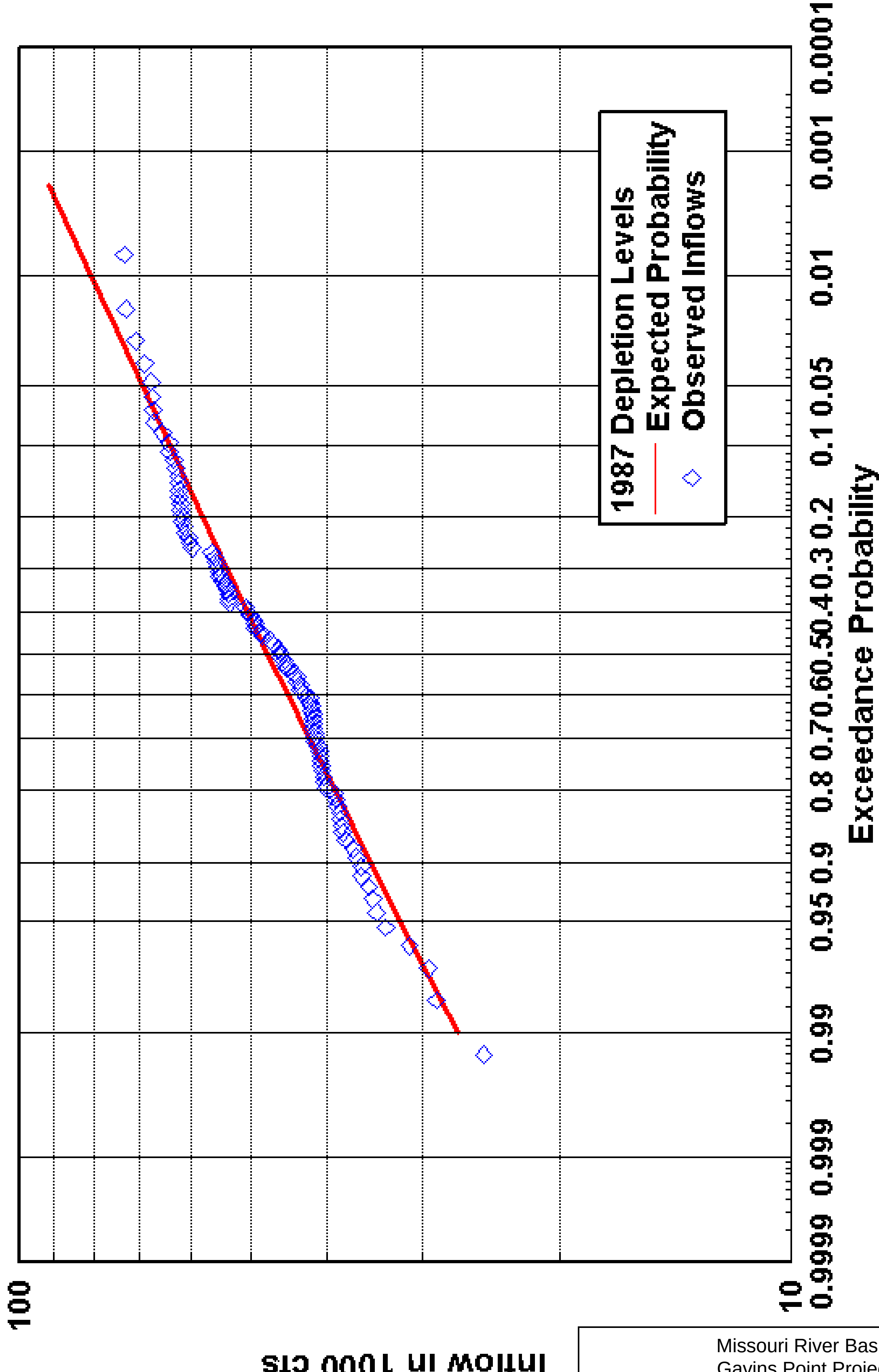
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-75

Missouri River Basin
Gavins Point Project
Reservoir, Intakes,
Spillway, and Powerhouse

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

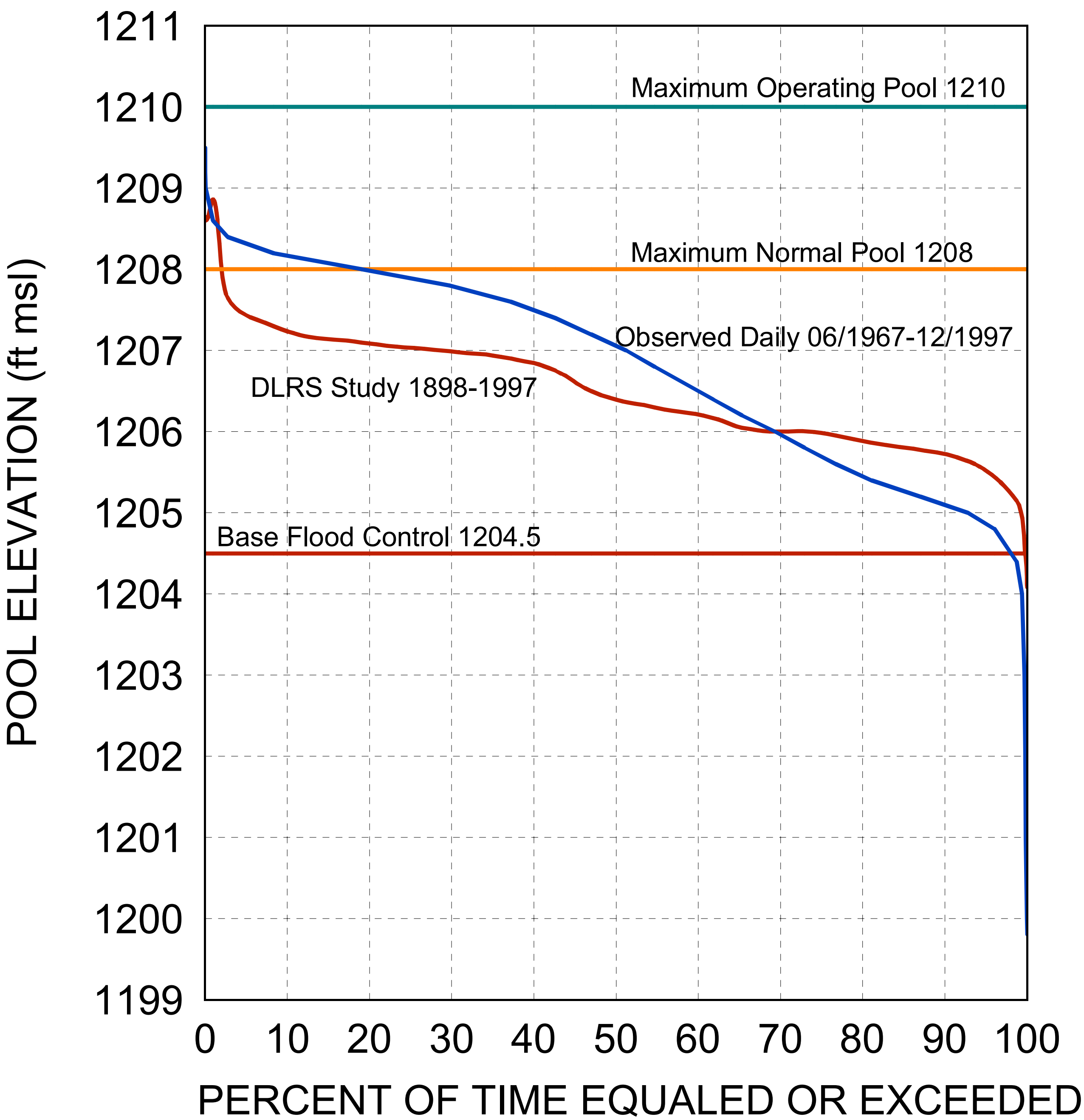
Plate II-76



Missouri River Basin
Gavins Point Project
Inflow Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

LEWIS & CLARK LAKE

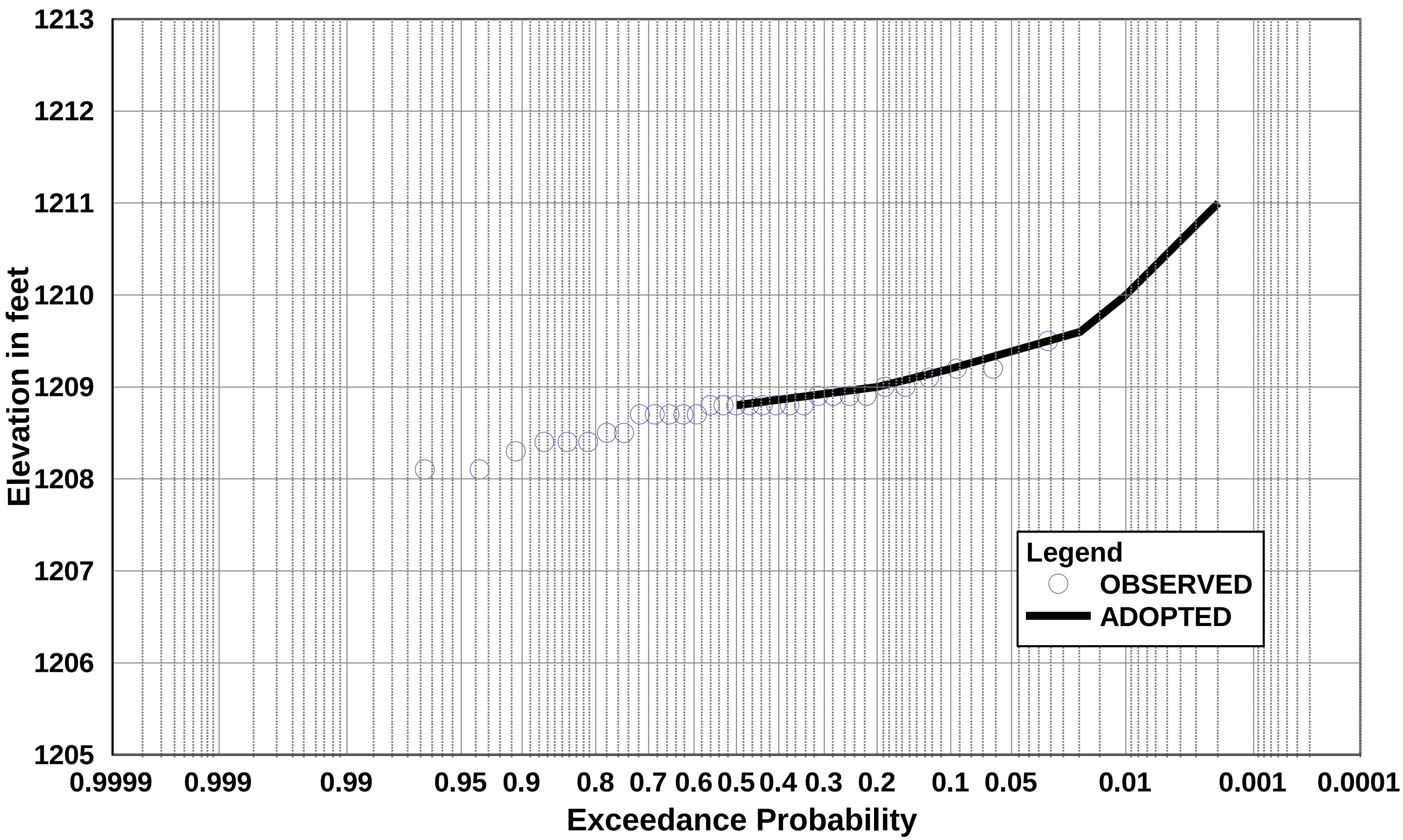
POOL DURATION RELATIONSHIP



Missouri River Basin
Gavins Point Dam Pool Elevation Duration
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-78

GAVINS POINT (LEWIS & CLARK LAKE)
POOL-PROBABILITY RELATIONSHIP



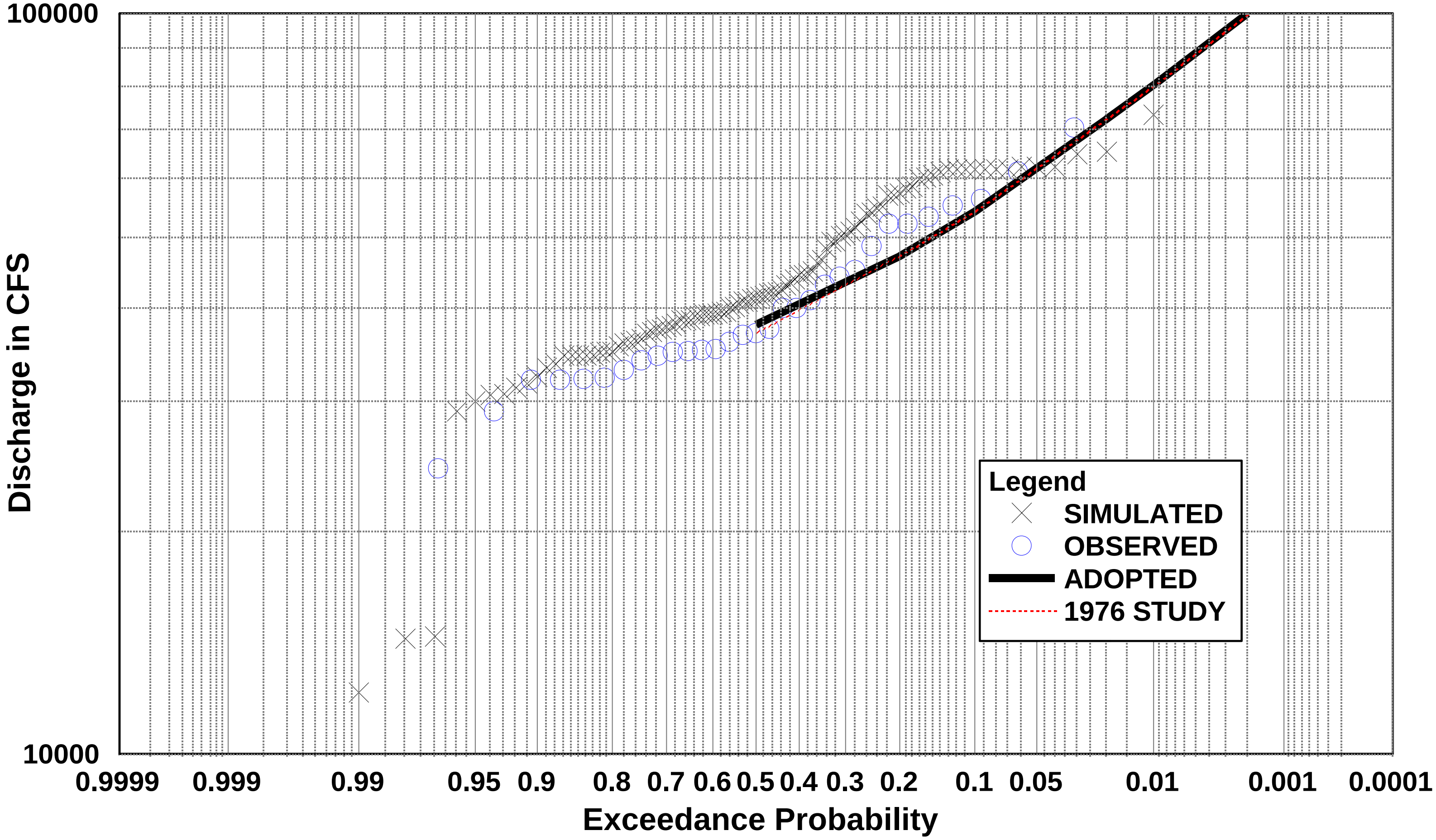
MAX POOL ELEVATION	=	1221.4
MAX OP. POOL ELEV	=	1210.0
MAX NORMAL POOL ELEV	=	1208.0
BASE FLOOD CONTROL	=	1204.5

Missouri River Basin
Gavins Point Project
Pool-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-79

GAVINS POINT (LEWIS & CLARK LAKE)
RELEASE-PROBABILITY RELATIONSHIP

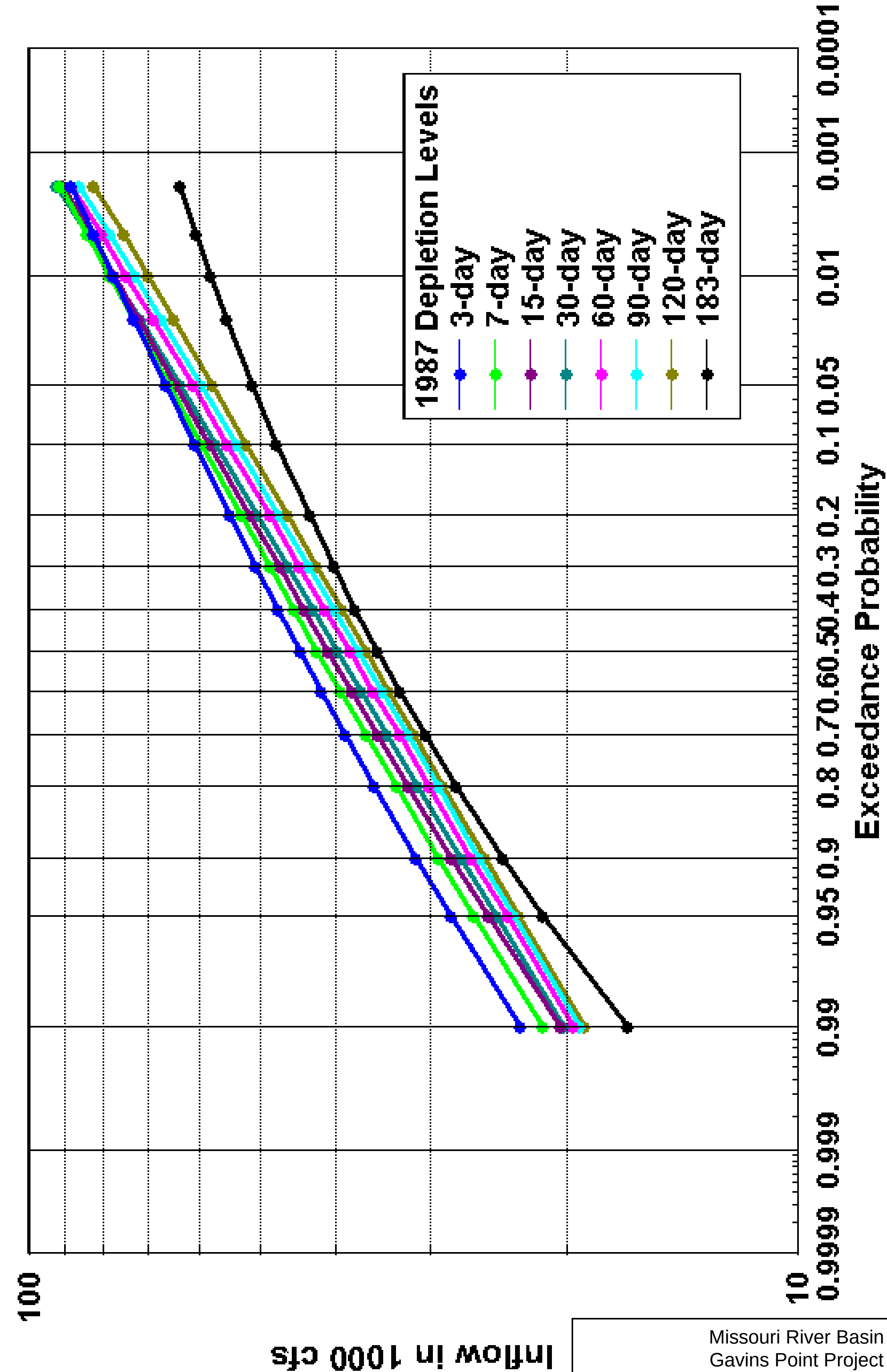


POWER PLANT CAPACITY = 36,000
OUTLET CAPACITY = 0
SPILLWAY CAPACITY = 584,000

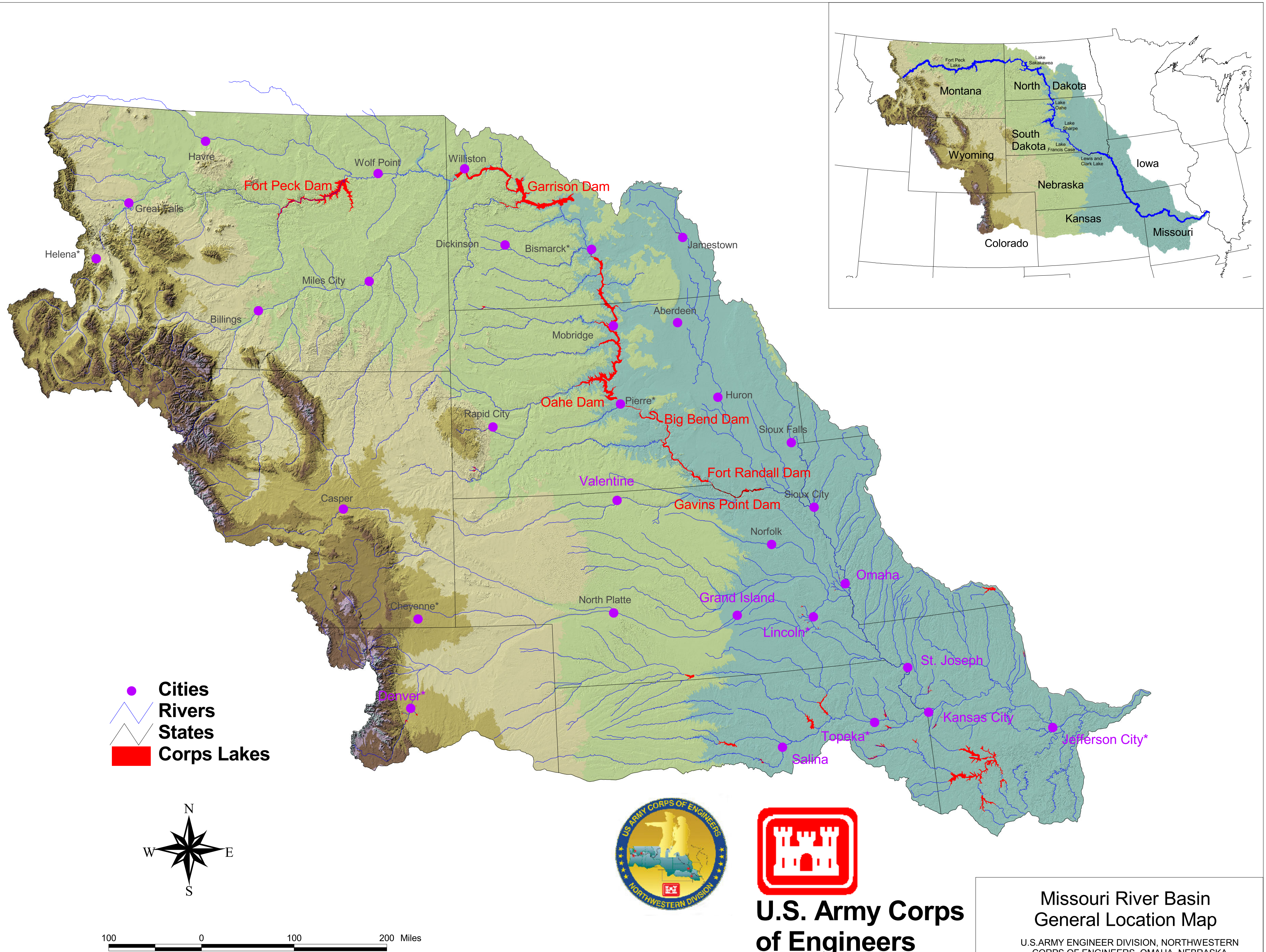
Missouri River Basin
Gavins Point Project
Release-Probability Relationship

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate II-80



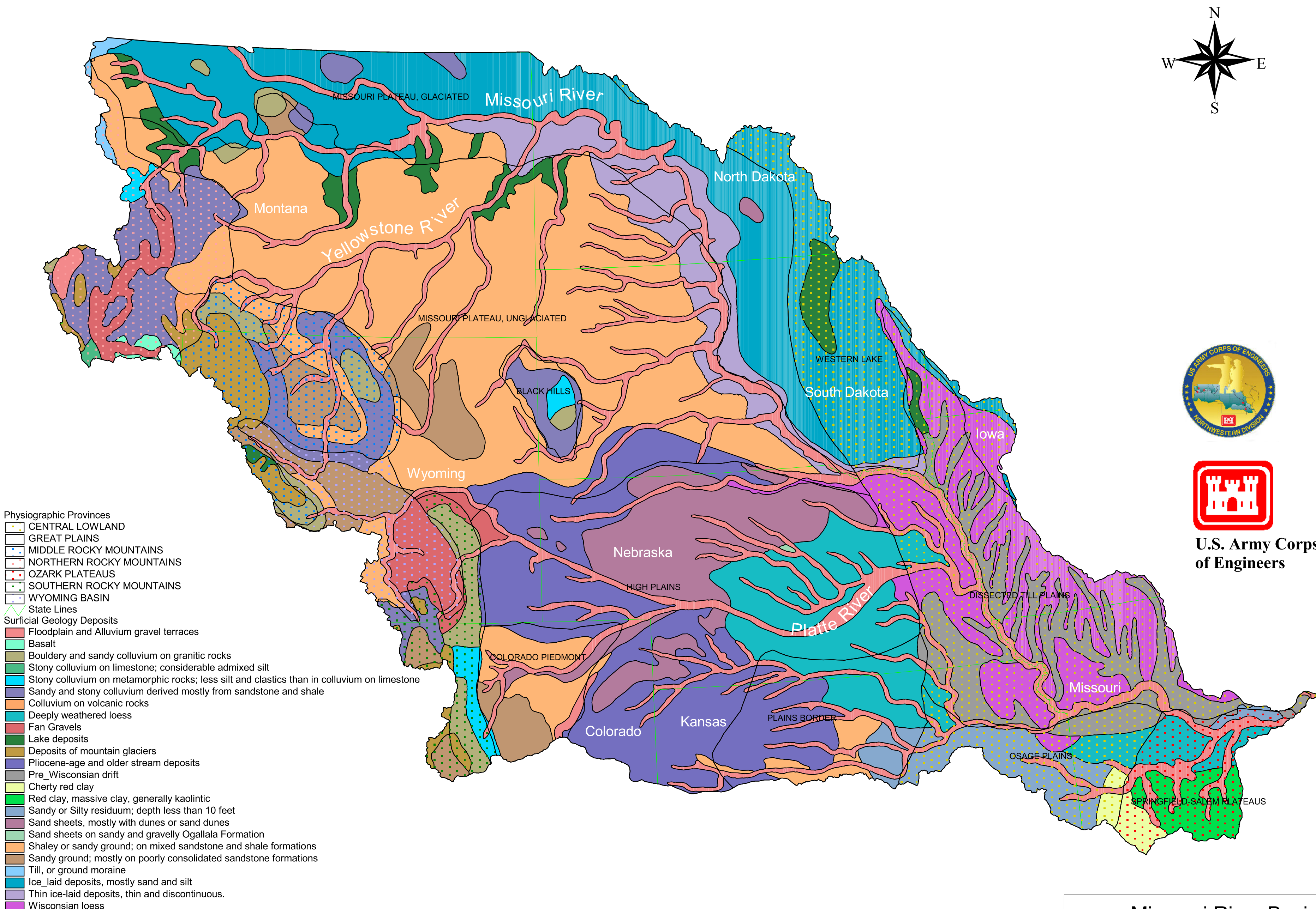
Missouri River Basin
Gavins Point Project
Inflow Volume Probabilities
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



Missouri River Basin
General Location Map

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-1



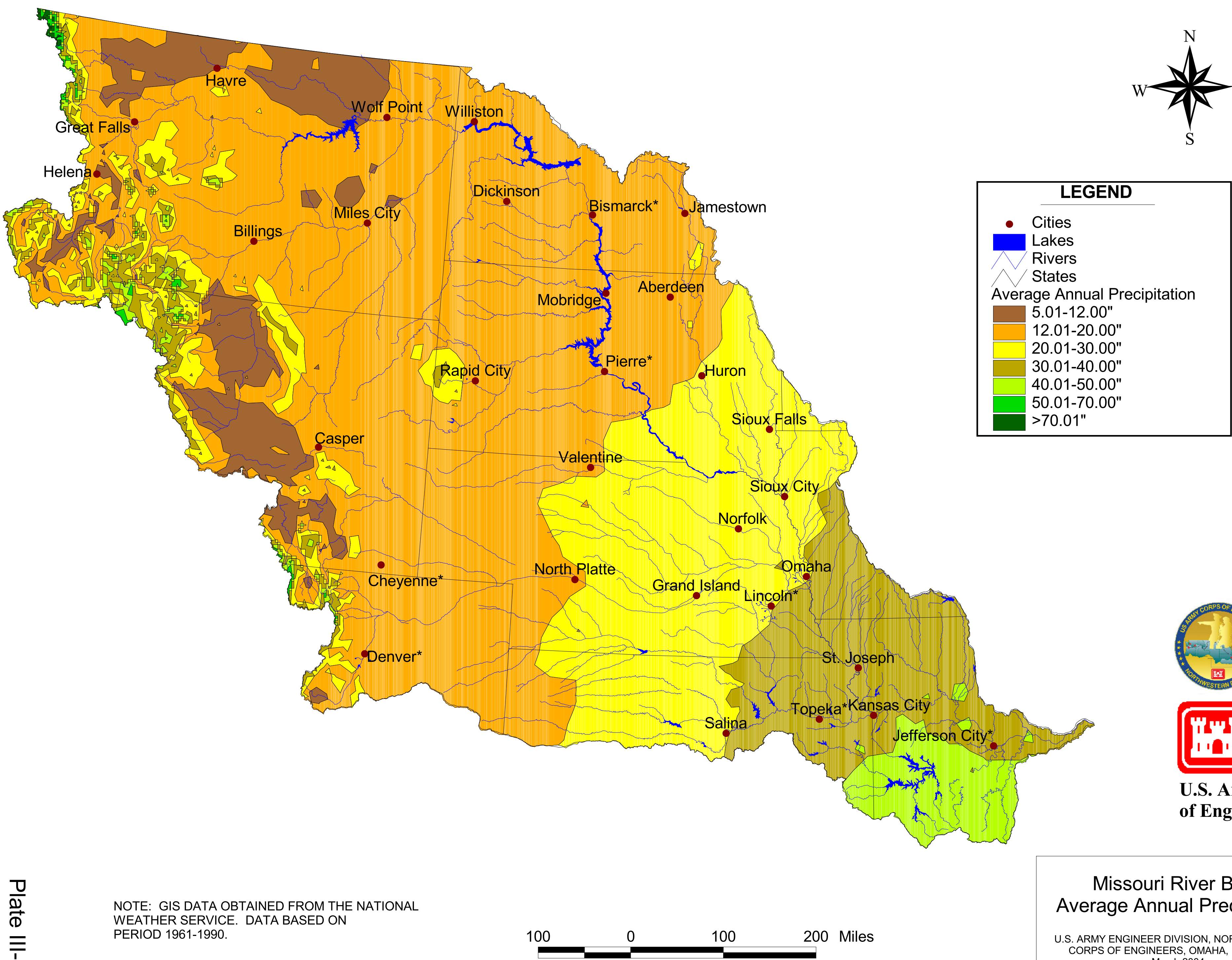
Note: Physiographic Provinces were based on the originators, Fenneman, N.M., and Johnson, D.W. in 1946 and GIS data was downloaded from the USGS website.
Surficial Geology Deposits were based on the originators, Clawges, R. and Price, C. in 1999 and GIS data was downloaded from the USGS

60 0 60 120 180 Miles

Missouri River Basin Physiographic Provinces & Surficial Geology

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-2



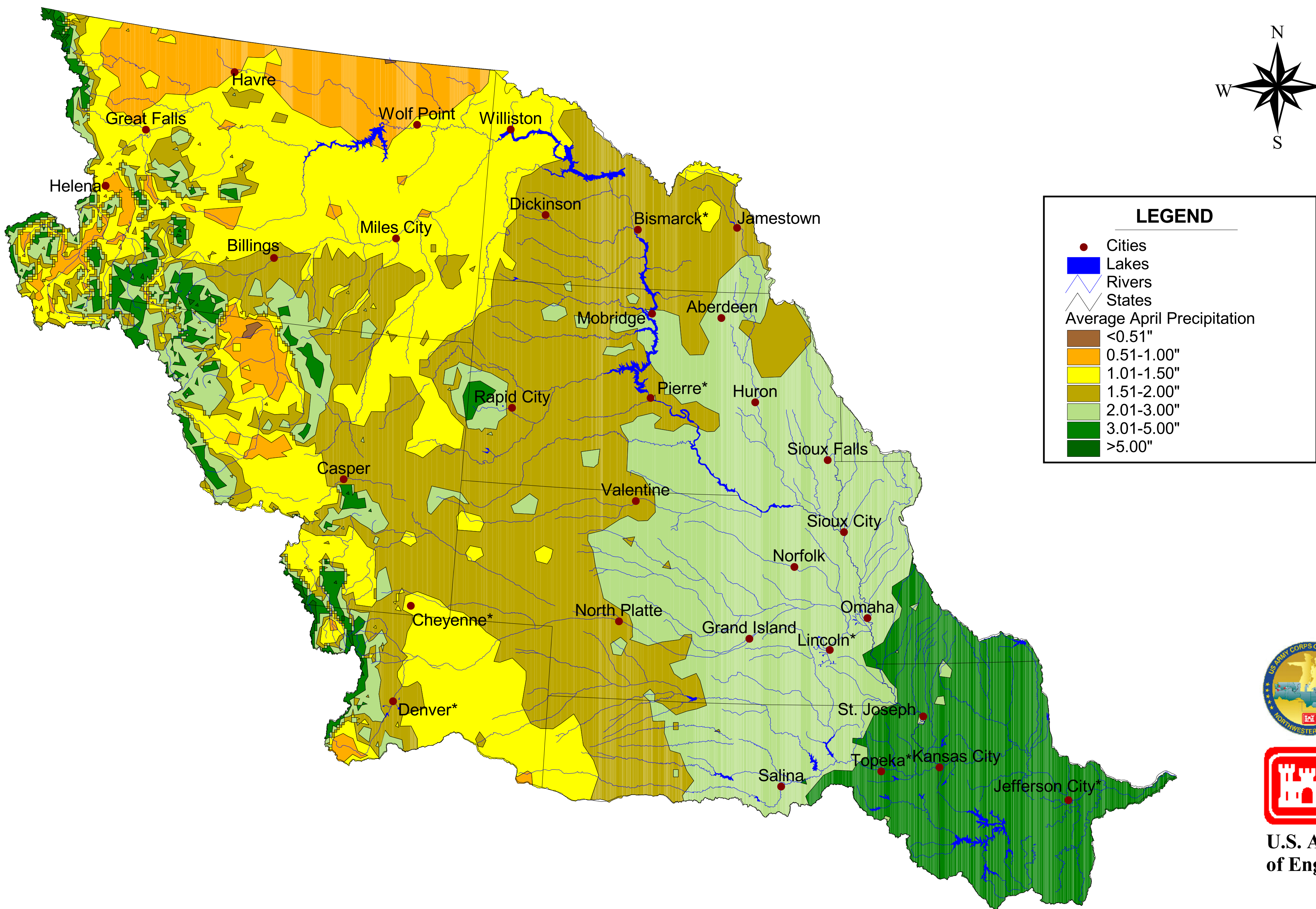
U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Average Annual Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-3



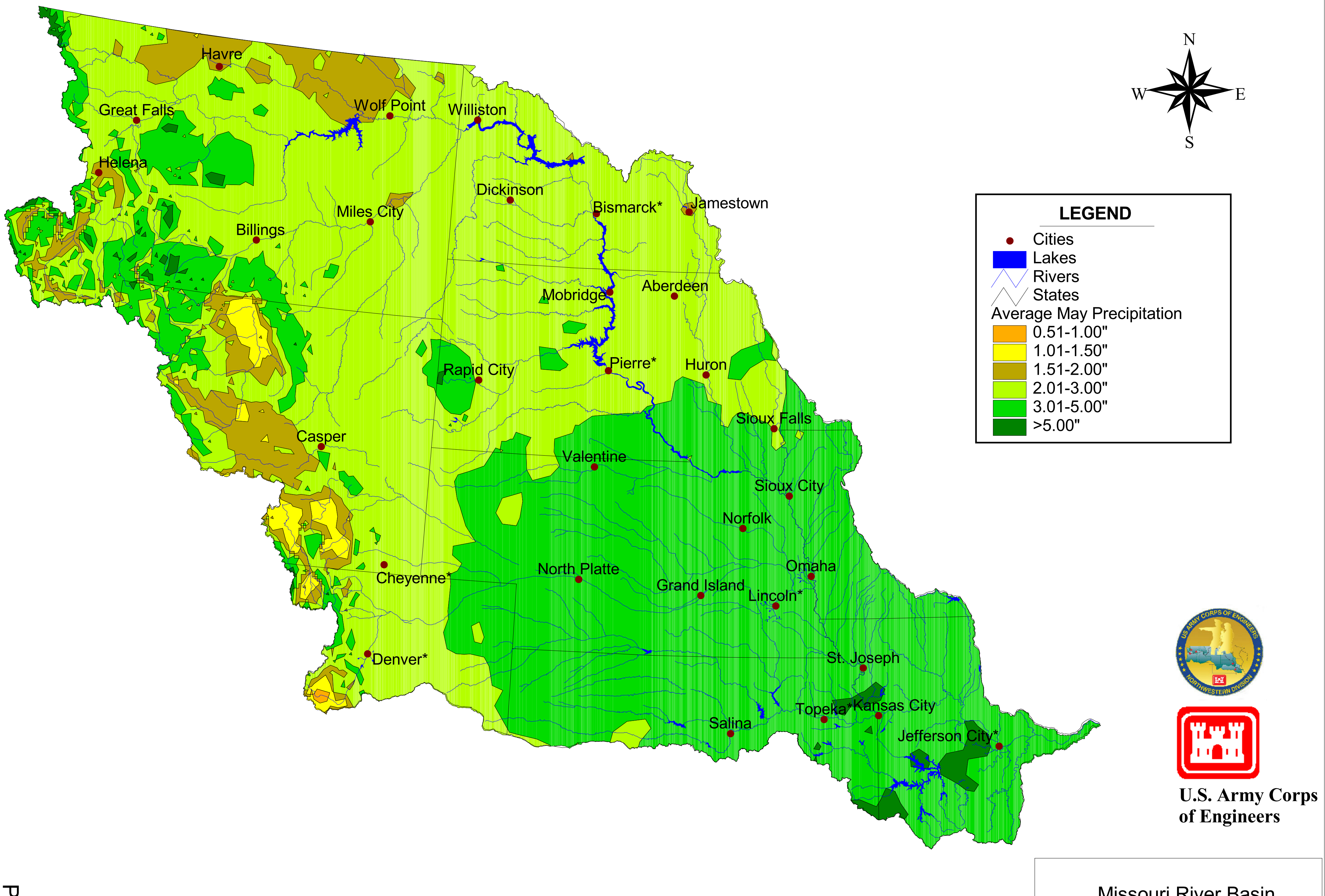
U.S. Army Corps of Engineers

Missouri River Basin
Average April Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

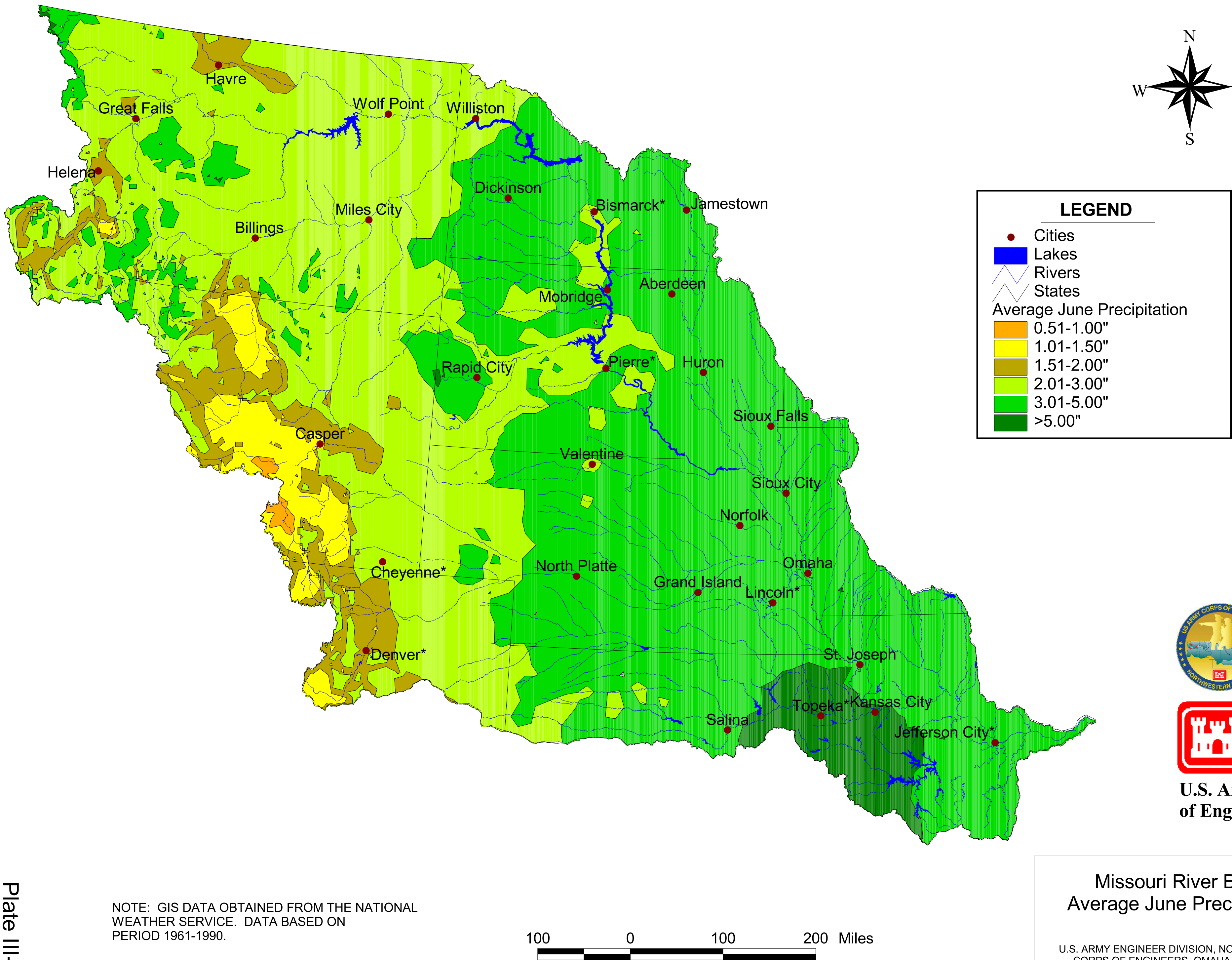
Plate III-4



NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Average May Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



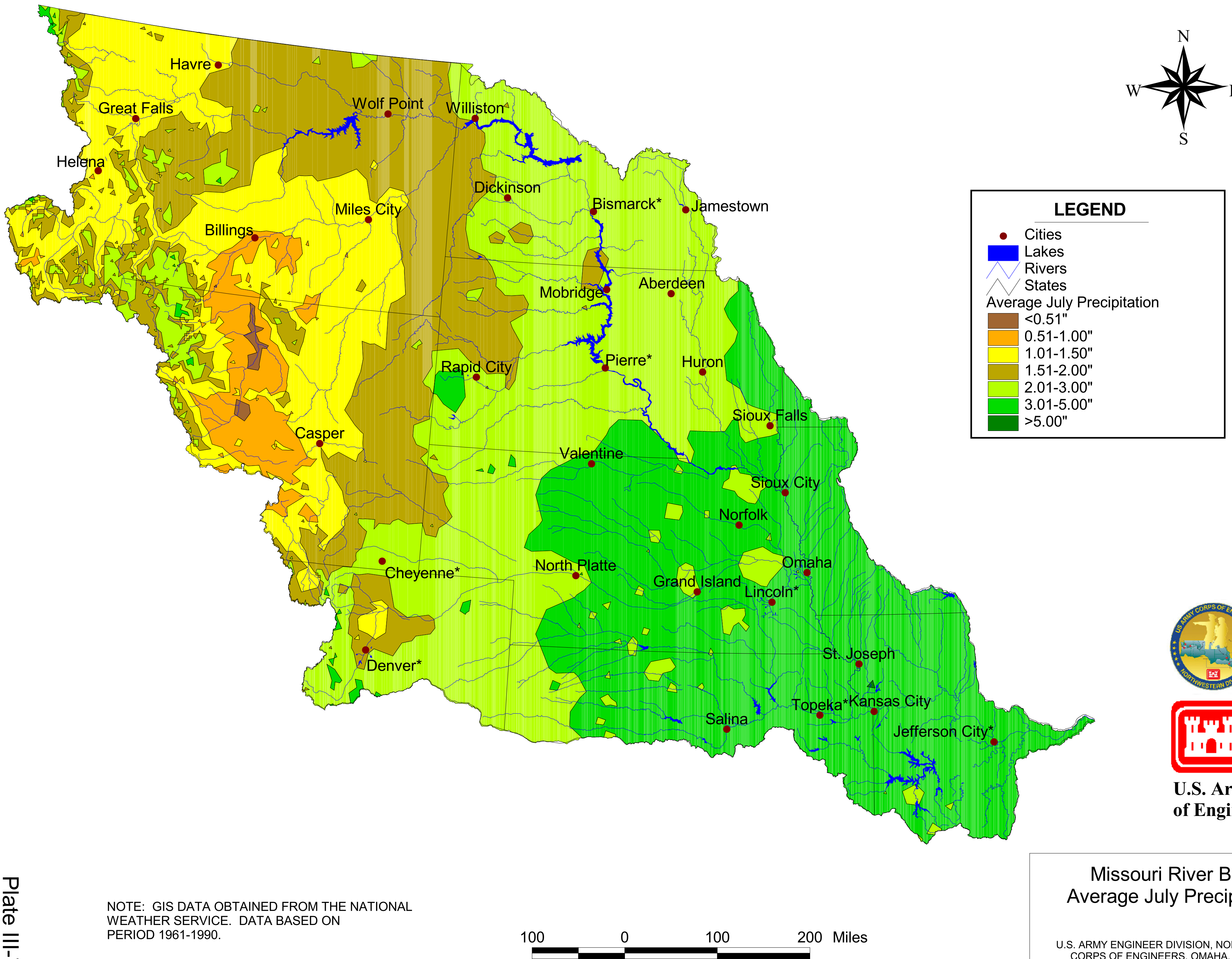
NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

U.S. Army Corps of Engineers

Missouri River Basin
Average June Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-6

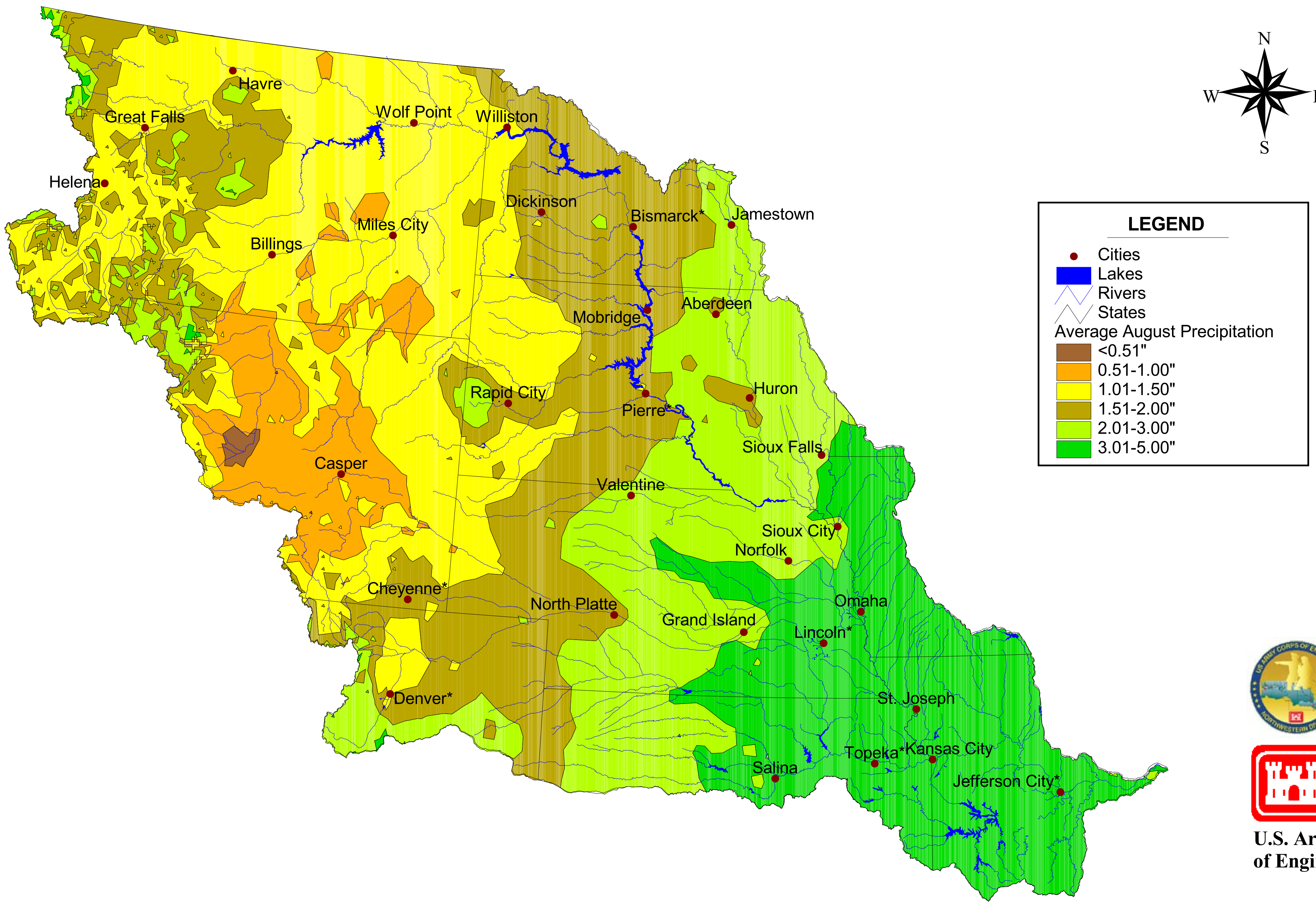


U.S. Army Corps of Engineers

Missouri River Basin
Average July Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.



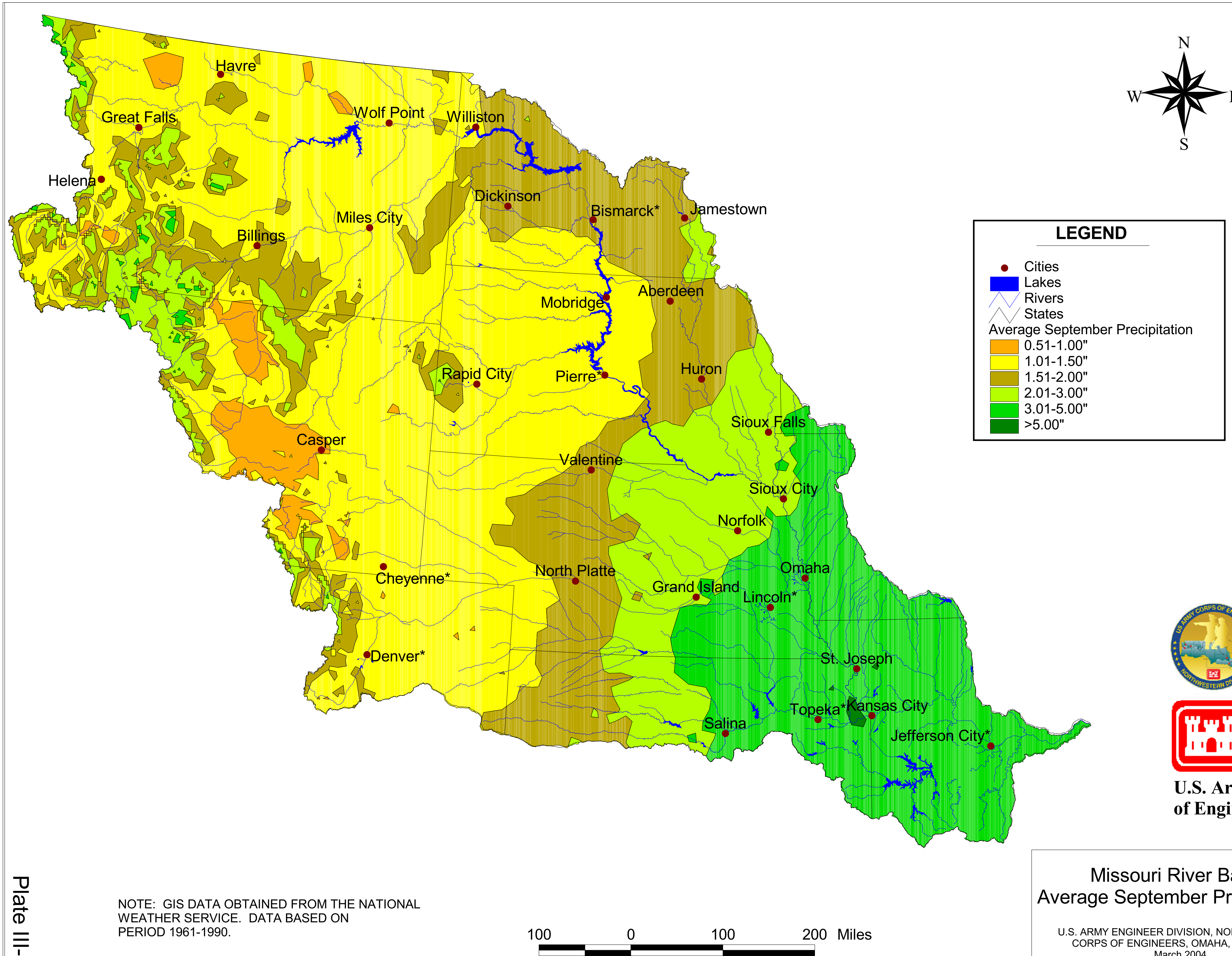
U.S. Army Corps of Engineers

Missouri River Basin
Average August Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

100 0 100 200 Miles



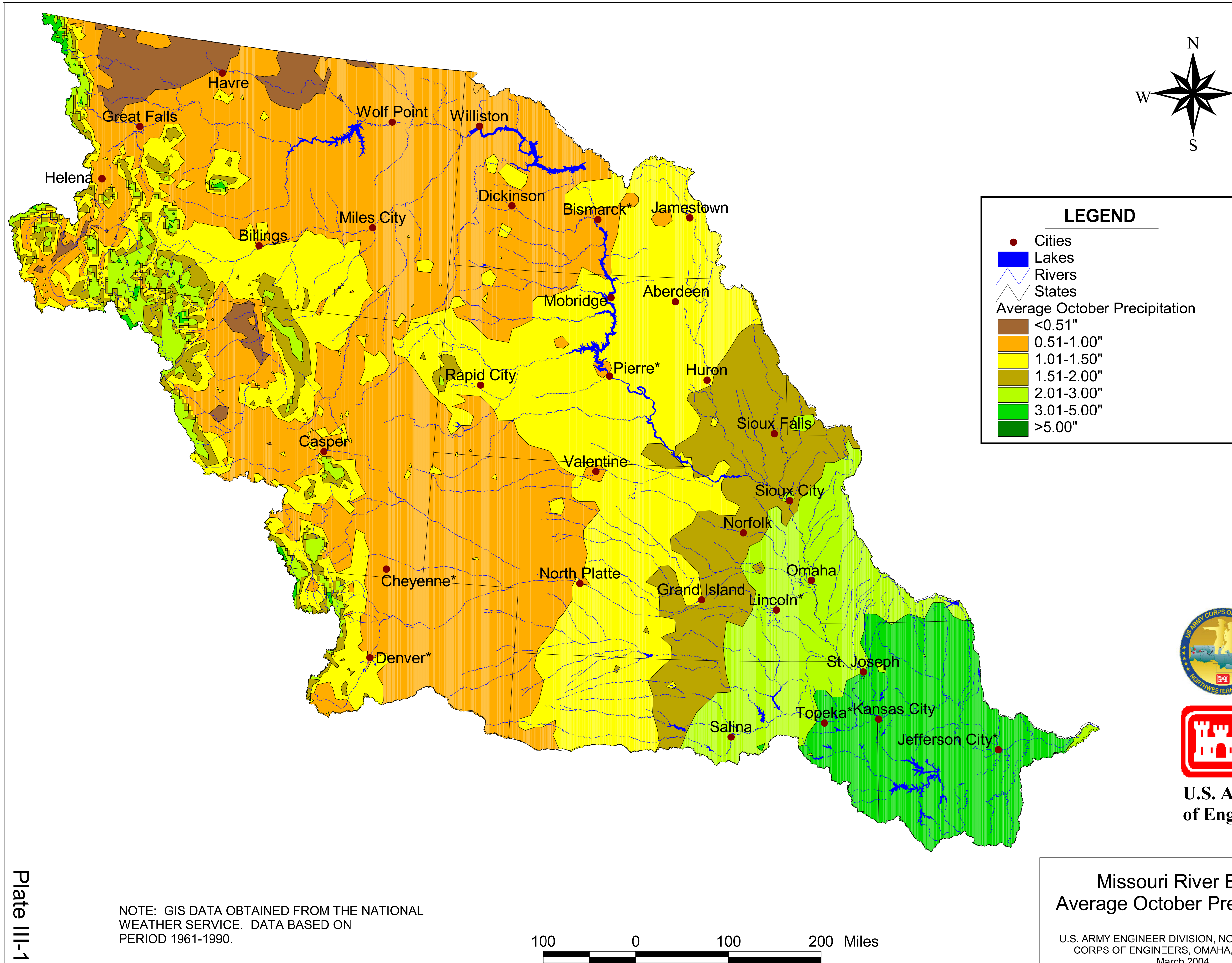
U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Average September Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-9

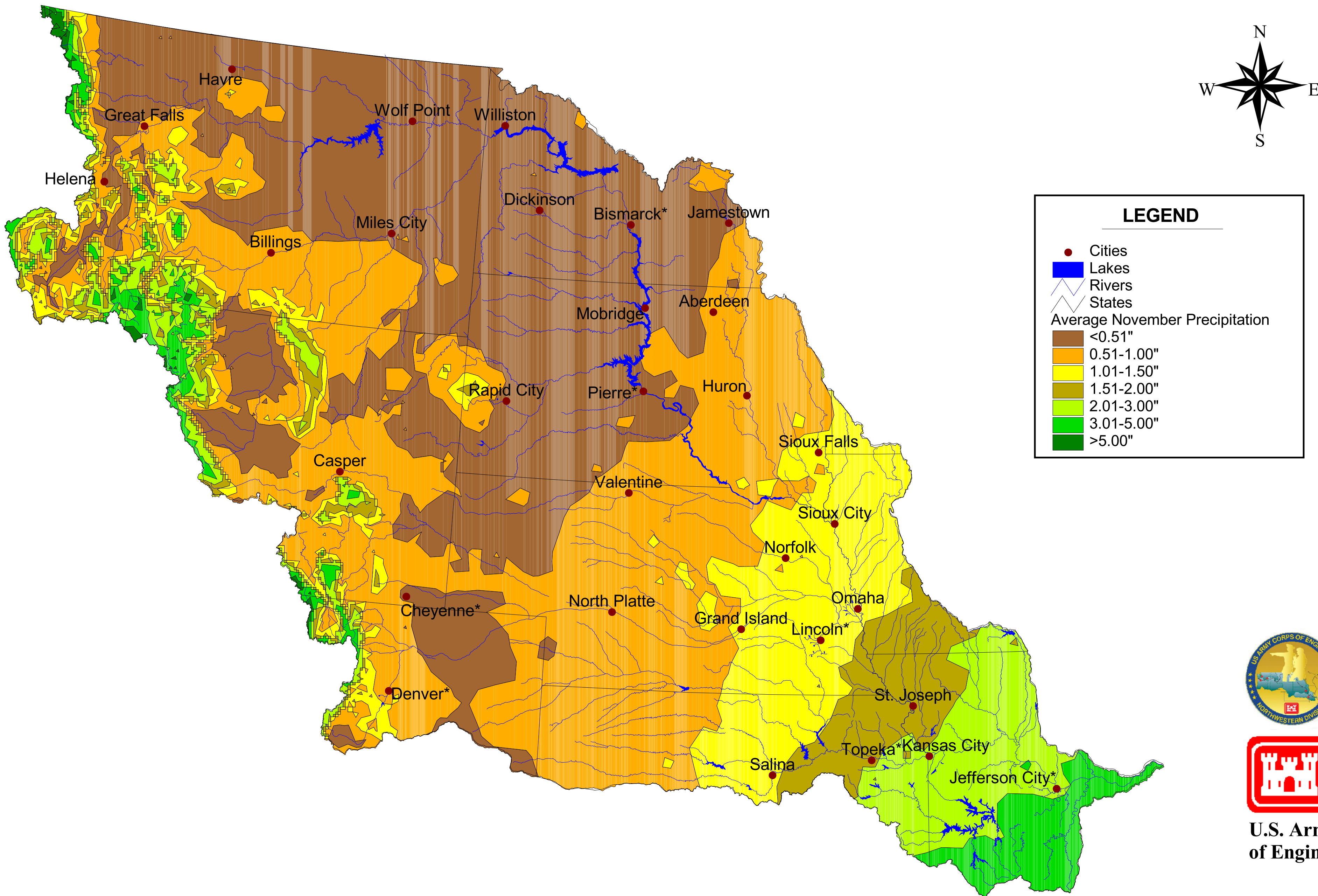


U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Average October Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



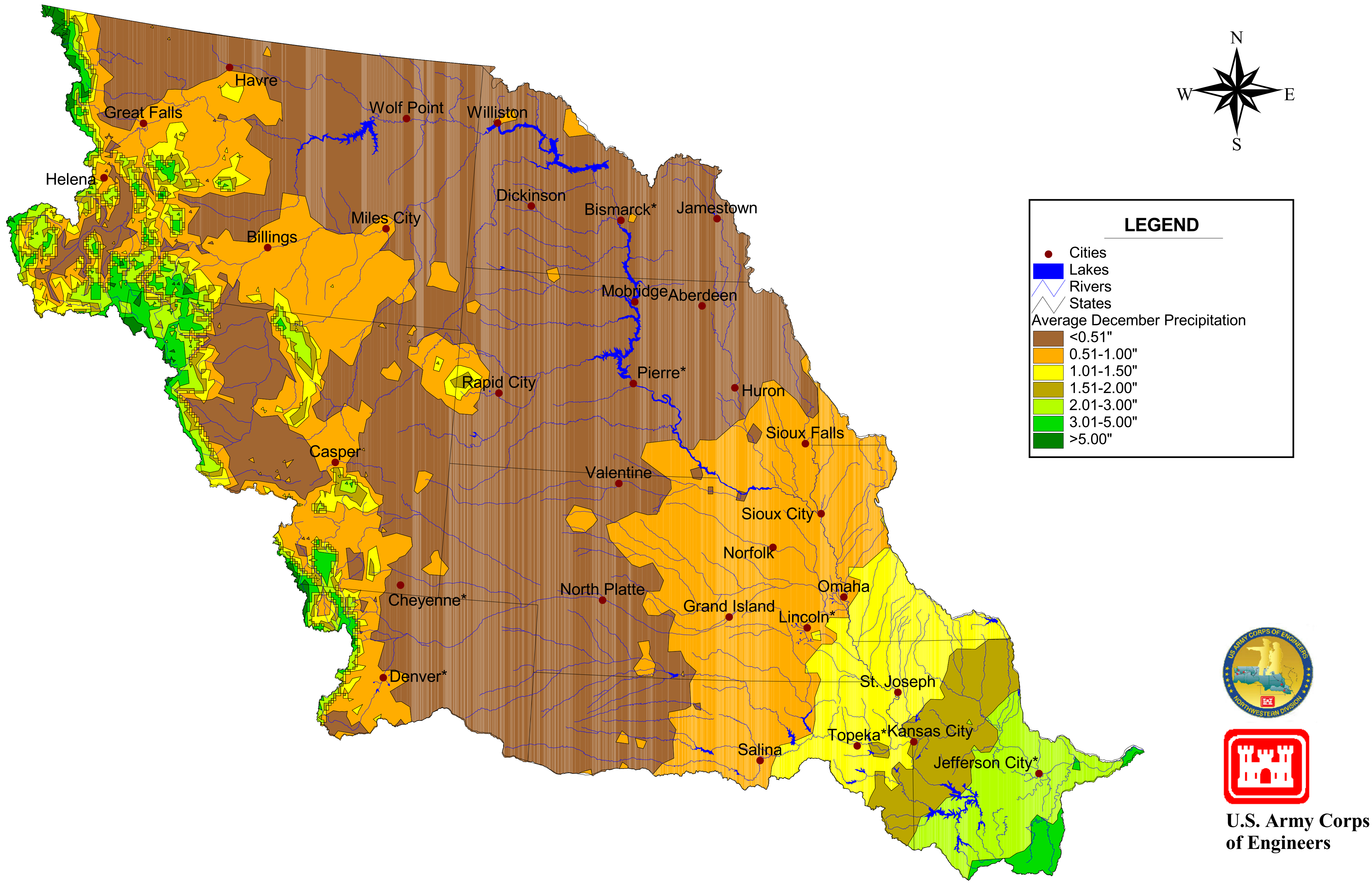
U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Average November Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-11



Missouri River Basin
Average December Precipitation

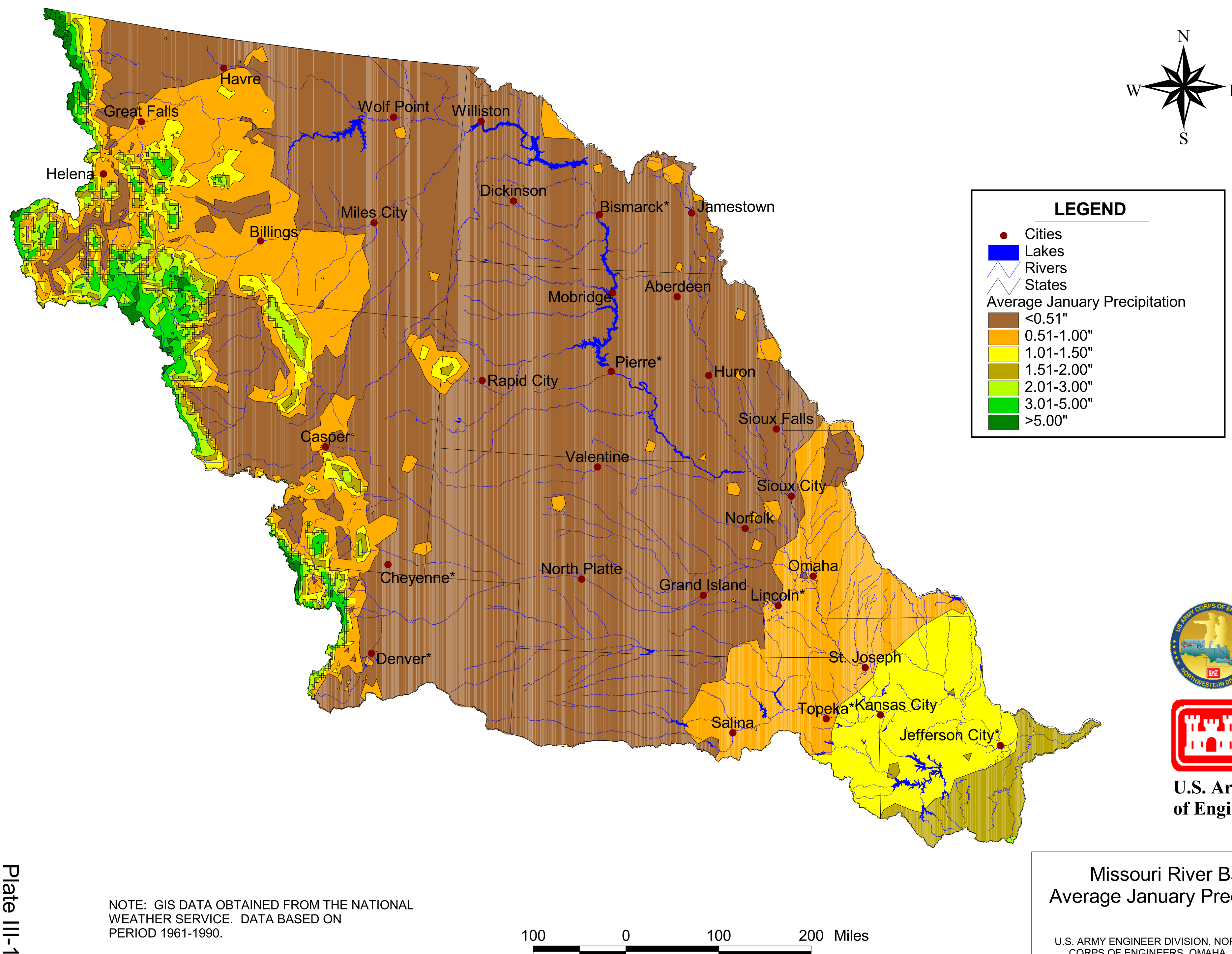
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Plate III-12

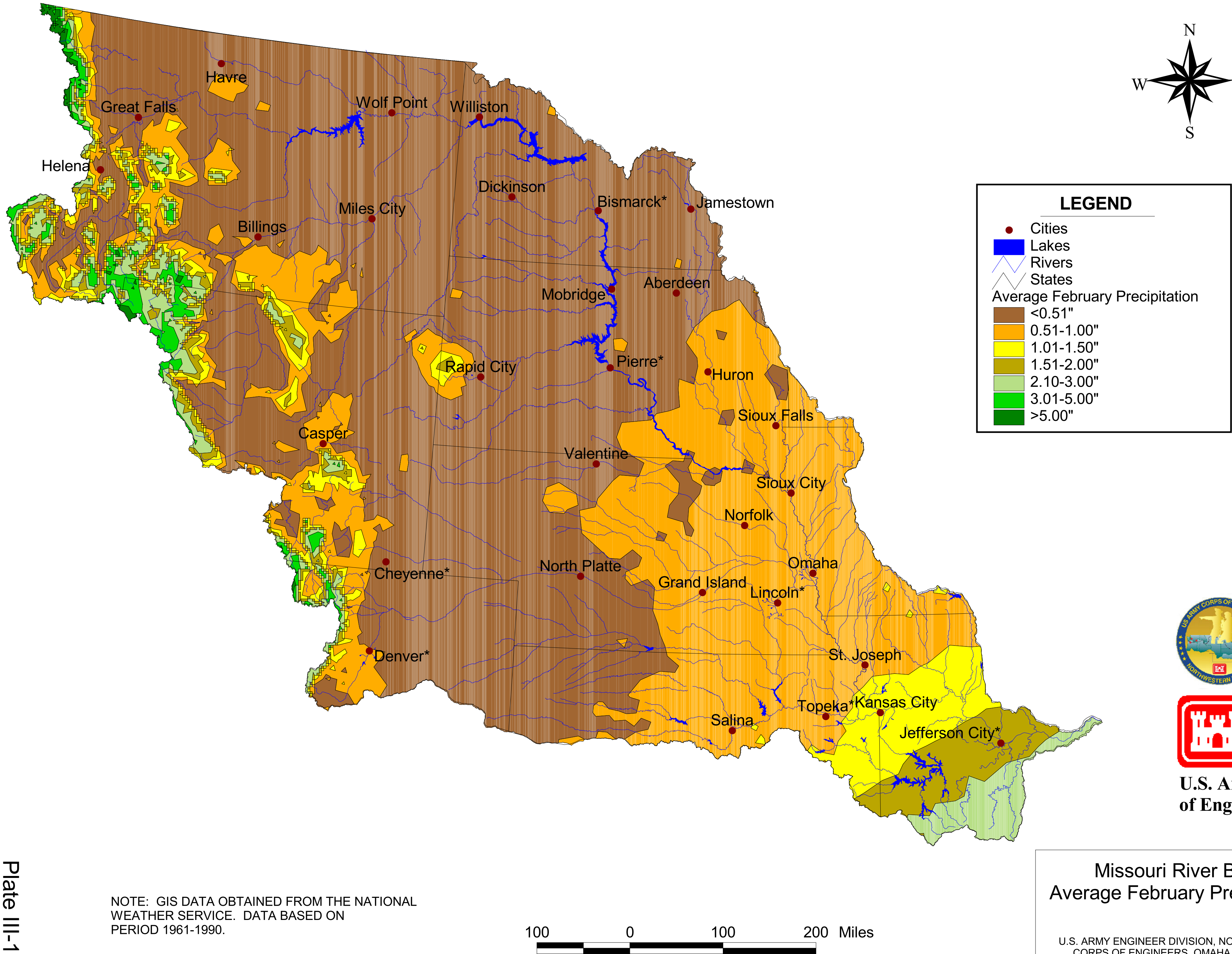
Missouri River Basin
Average January Precipitation

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.



U.S. Army Corps of Engineers

Missouri River Basin
Average February Precipitation

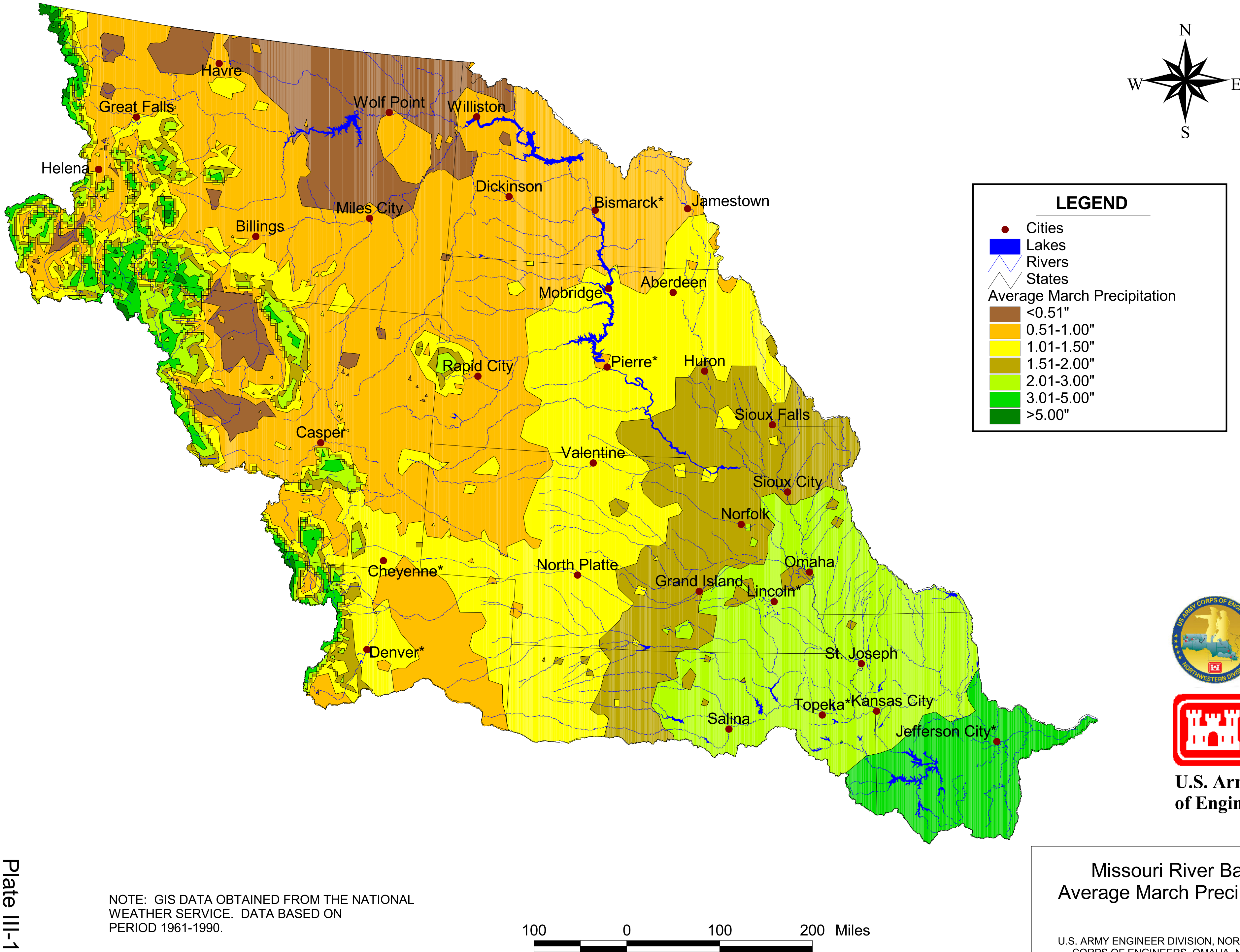
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Plate III-14

Missouri River Basin
Average March Precipitation

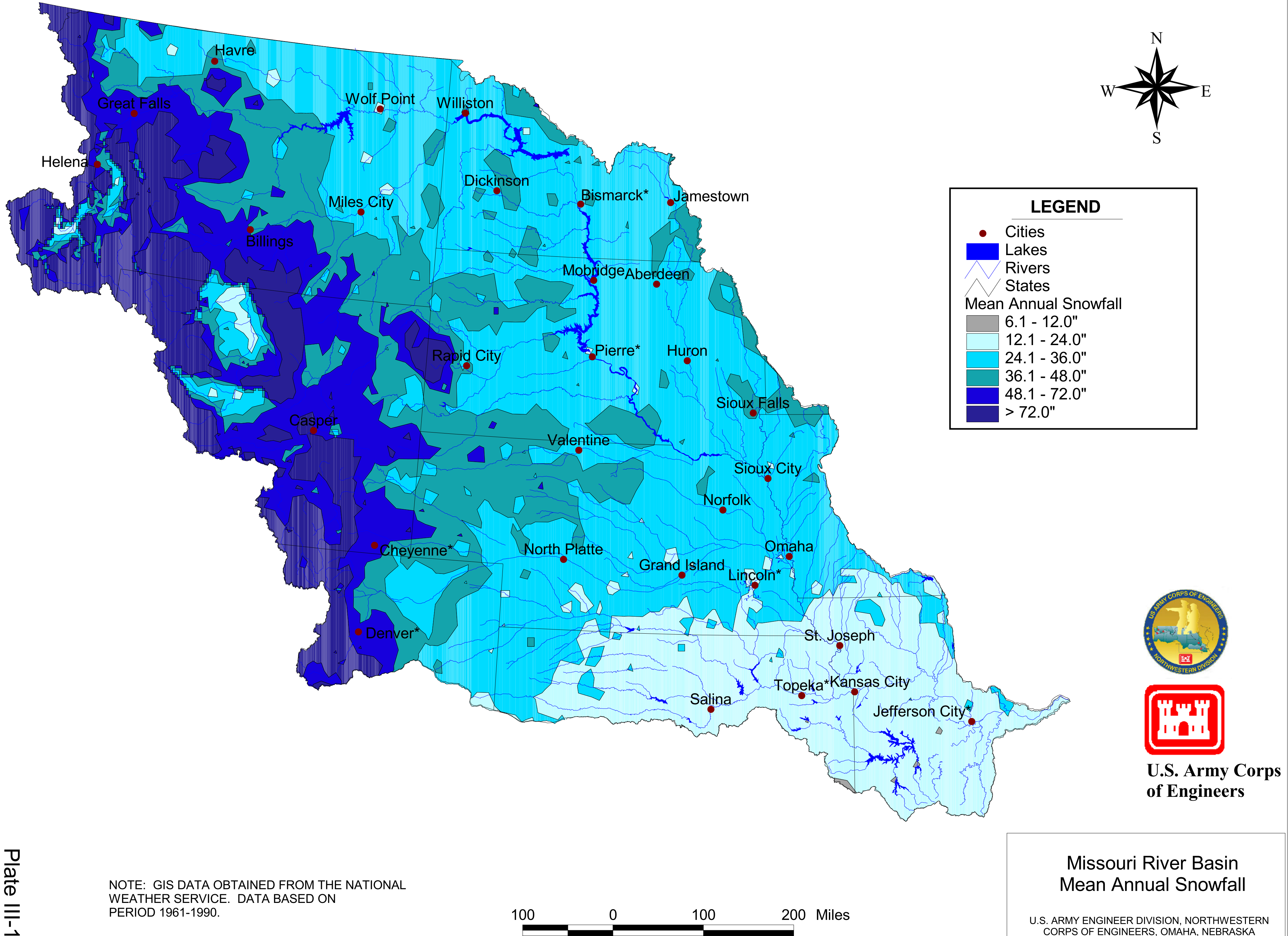
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Plate III-15

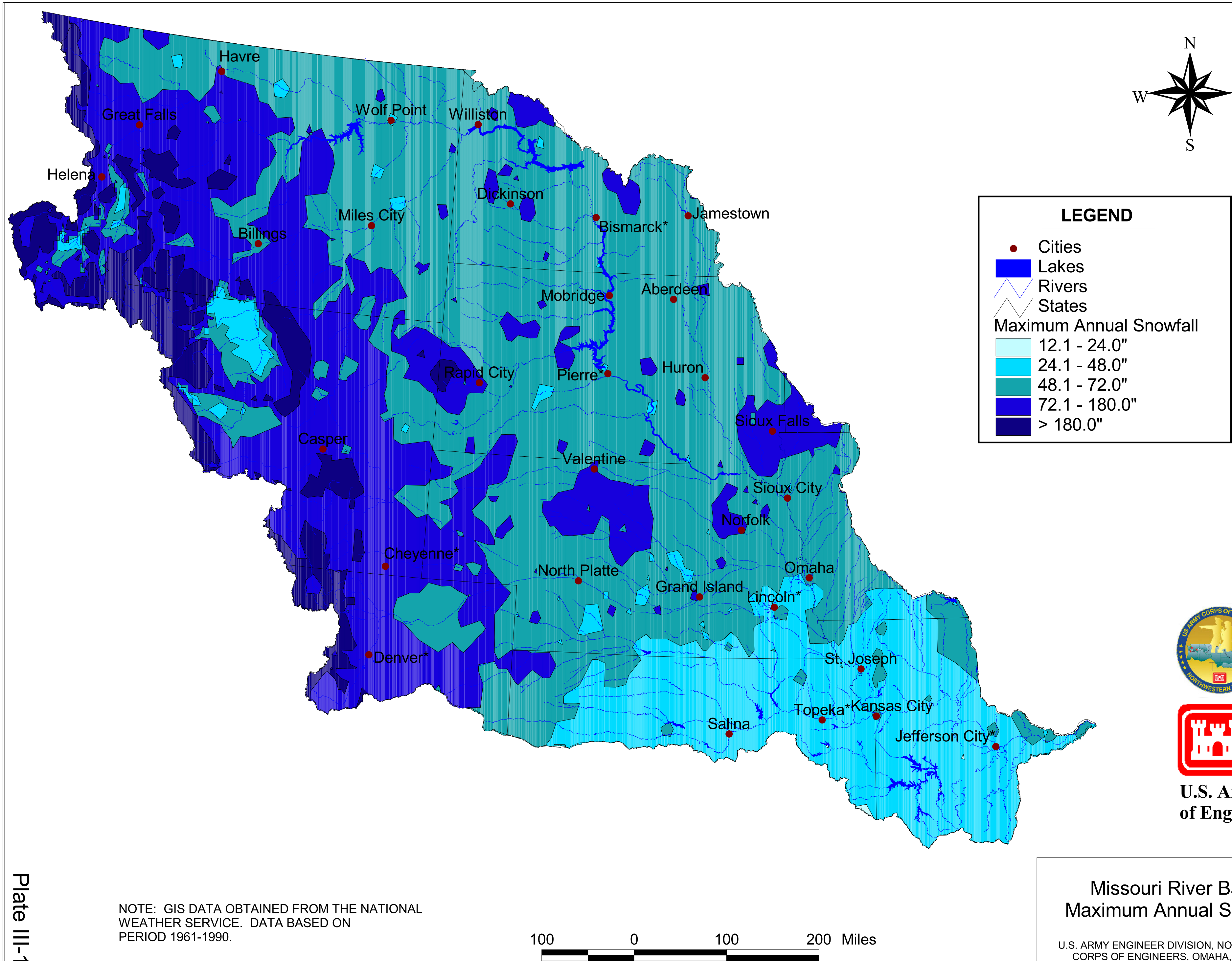


NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

U.S. Army Corps of Engineers

Missouri River Basin
Mean Annual Snowfall

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



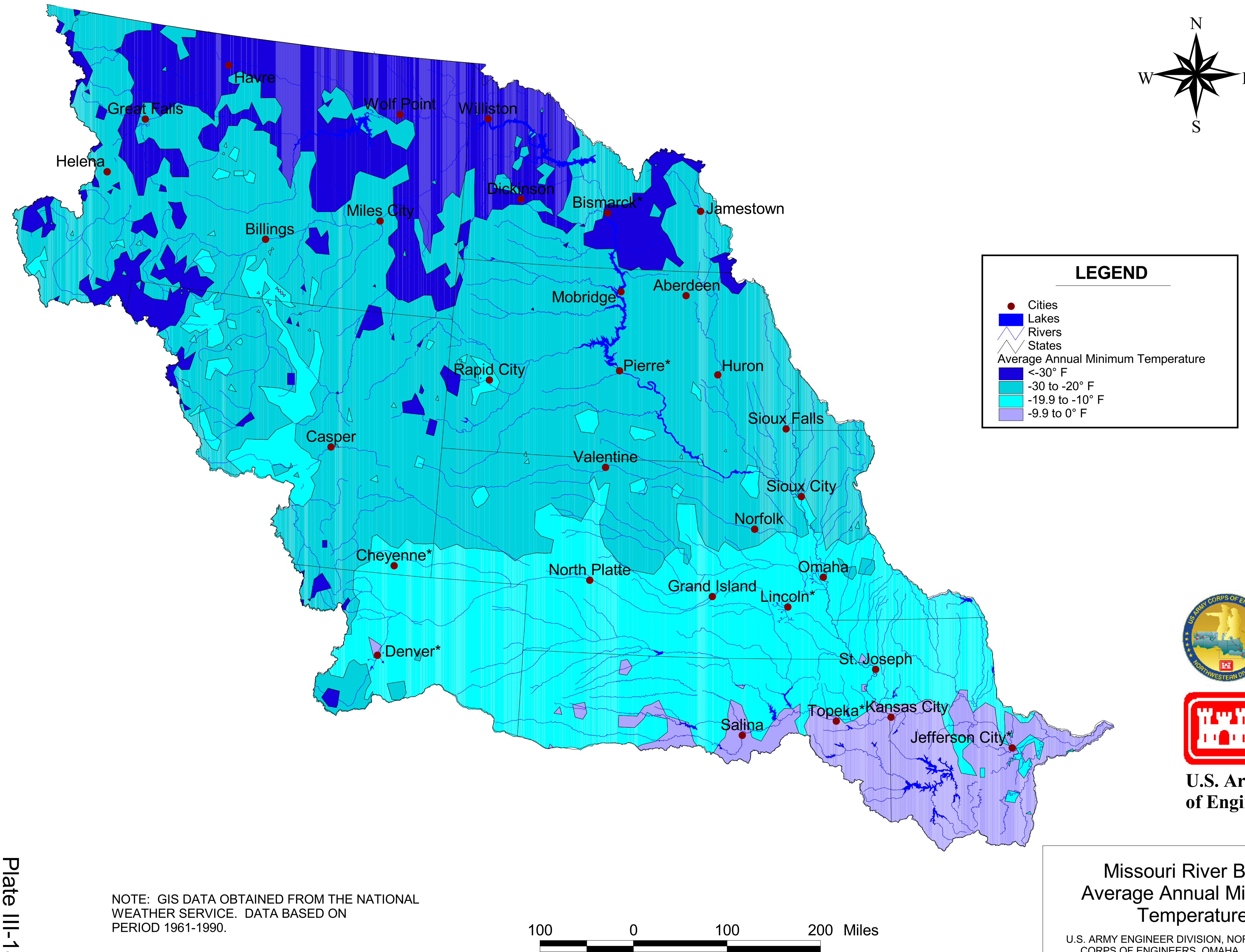
U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Maximum Annual Snowfall

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-17



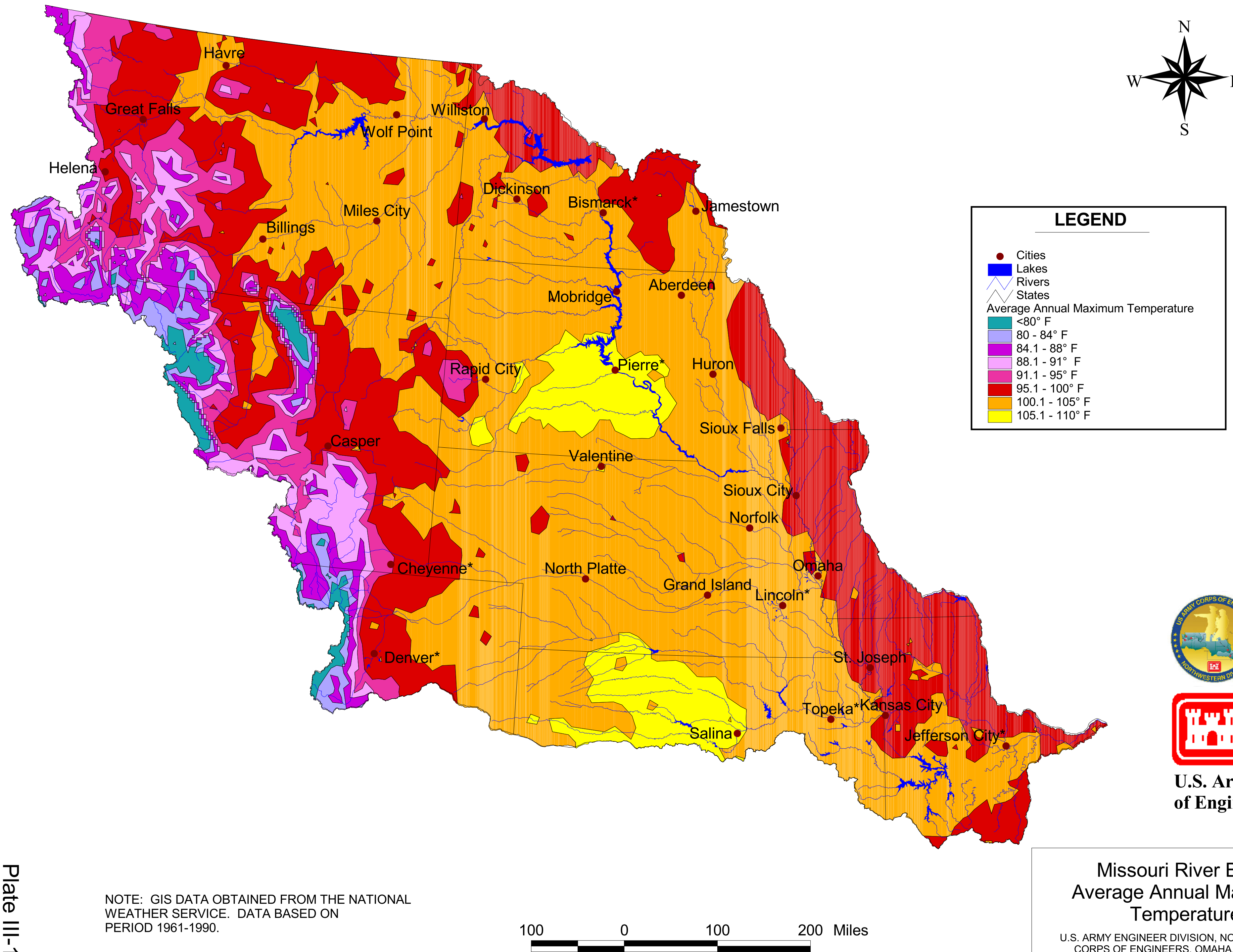
U.S. Army Corps of Engineers

Missouri River Basin Average Annual Minimum Temperature

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Plate III-18

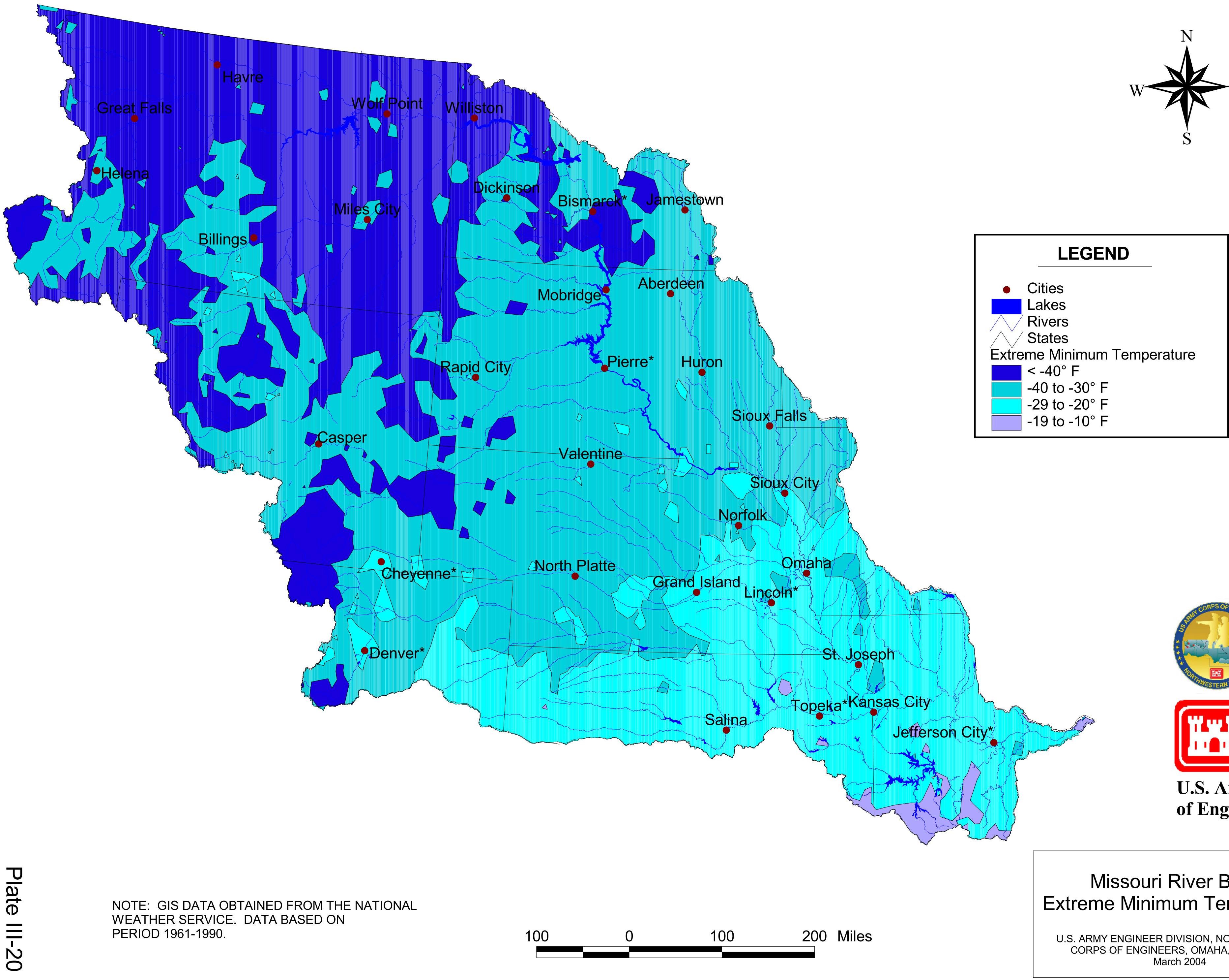


NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

U.S. Army Corps of Engineers

Missouri River Basin
Average Annual Maximum Temperature

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004



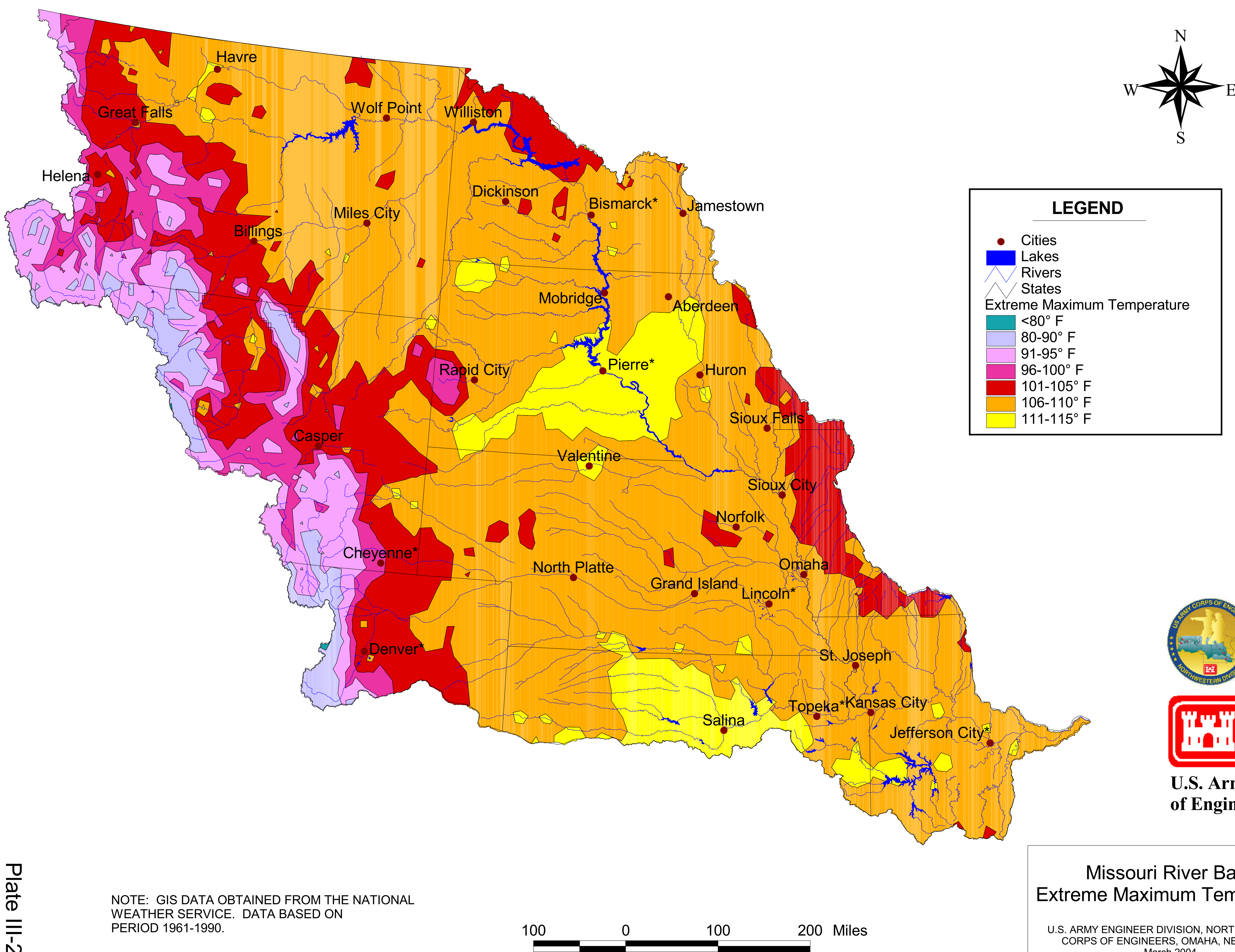
U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Extreme Minimum Temperature

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-20



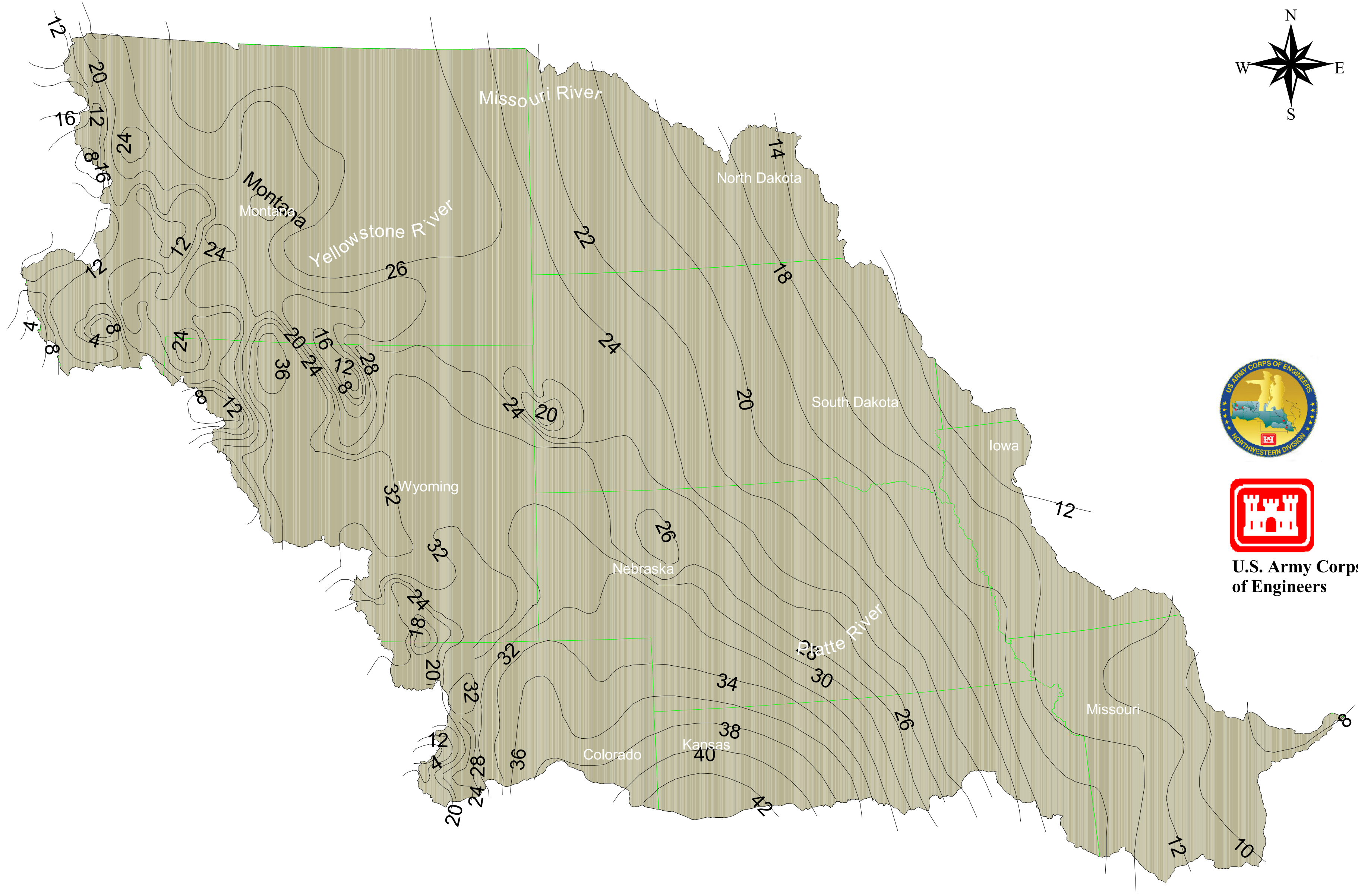
U.S. Army Corps of Engineers

NOTE: GIS DATA OBTAINED FROM THE NATIONAL WEATHER SERVICE. DATA BASED ON PERIOD 1961-1990.

Missouri River Basin
Extreme Maximum Temperature

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-21



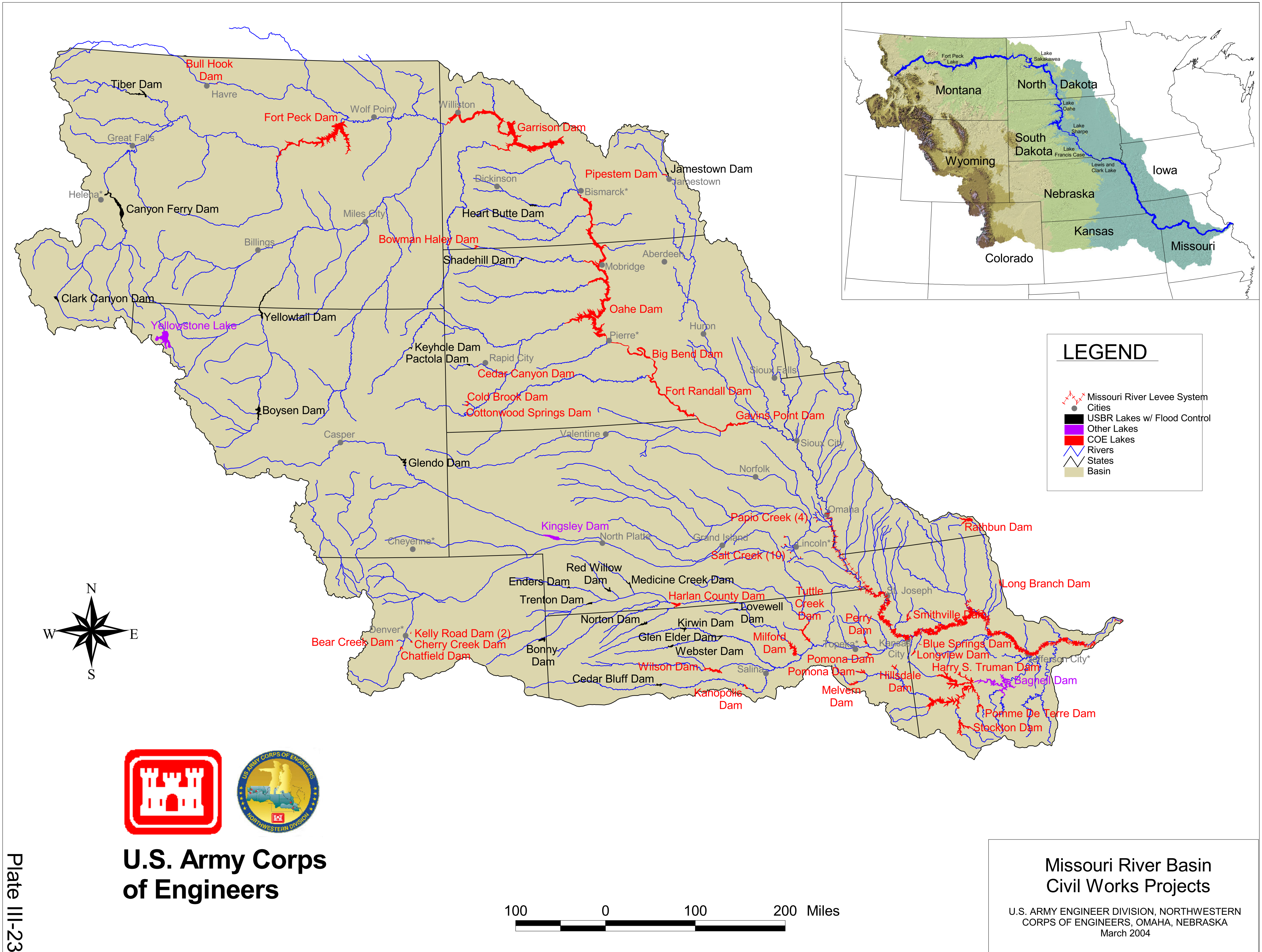
60 0 60 120 180 Miles

Note: Data obtained from the USGS.

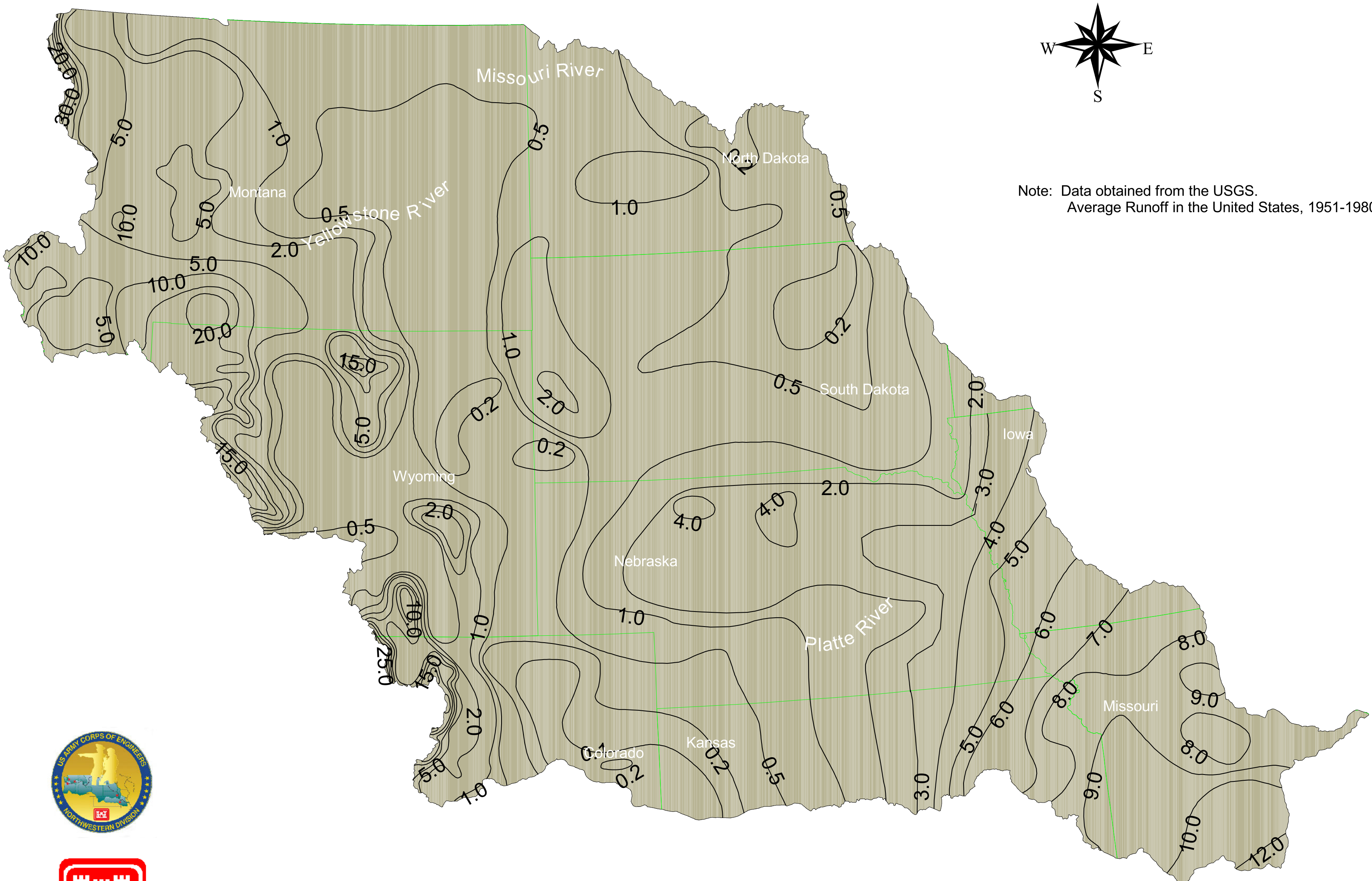
Missouri River Basin Average Annual Net Lake Evaporation in Inches

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

U.S. Army Corps of Engineers



Missouri River Basin
Civil Works Projects
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004
LEGEND
Missouri River Levee System
Cities
USBR Lakes w/ Flood Control
Other Lakes
COE Lakes
Rivers
States
Basin
U.S. Army Corps of Engineers
100 0 100 200 Miles
N
S
E
W
Montana
North Dakota
South Dakota
Wyoming
Nebraska
Iowa
Kansas
Missouri
Colorado
Fort Peck Lake
Lake Sakakawea
Lake Oahe
Lake Sharpe
Lake Francis Case
Lewis and Clark Lake
Tiber Dam
Bull Hook Dam
Havre
Fort Peck Dam
Wolf Point
Williston
Garrison Dam
Great Falls
Helena*
Canyon Ferry Dam
Miles City
Billings
Dickinson
Heart Butte Dam
Pipestem Dam
Bismarck*
Jamestown Dam
Jamestown
Bowman Haley Dam
Shadehill Dam
Aberdeen
Mobridge
Clark Canyon Dam
Yellowtail Dam
Yellowstone Lake
Oahe Dam
Pierre*
Huron
Big Bend Dam
Keyhole Dam
Pactola Dam
Rapid City
Cedar Canyon Dam
Cold Brook Dam
Cottonwood Springs Dam
Sioux Falls
Fort Randall Dam
Gavins Point Dam
Sioux City
Boysen Dam
Casper
Valentine
Glendo Dam
Norfolk
Omaha
Papio Creek (4)
Kingsley Dam
North Platte
Grand Island
Lincoln*
Salt Creek (10)
Cheyenne*
Rathbun Dam
Red Willow Dam
Enders Dam
Medicine Creek Dam
Trenton Dam
Harlan County Dam
Lovewell Dam
Tuttle Creek Dam
St. Joseph
Long Branch Dam
Norton Dam
Kirwin Dam
Perry Dam
Smithville Dam
Glen Elder Dam
Milford Dam
Webster Dam
Topeka*
Kansas City
Blue Springs Dam
Longview Dam
Denver*
Kelly Road Dam (2)
Cherry Creek Dam
Chatfield Dam
Bear Creek Dam
Bonny Dam
Pomona Dam
Harry S. Truman Dam
Jefferson City*
Wilson Dam
Salina
Hillsdale Dam
Bagnell Dam
Cedar Bluff Dam
Kanopolis Dam
Melvern Dam
Pomme De Terre Dam
Stockton Dam



Note: Data obtained from the USGS.
Average Runoff in the United States, 1951-1980

60 0 60 120 180 Miles

U.S. Army Corps of Engineers

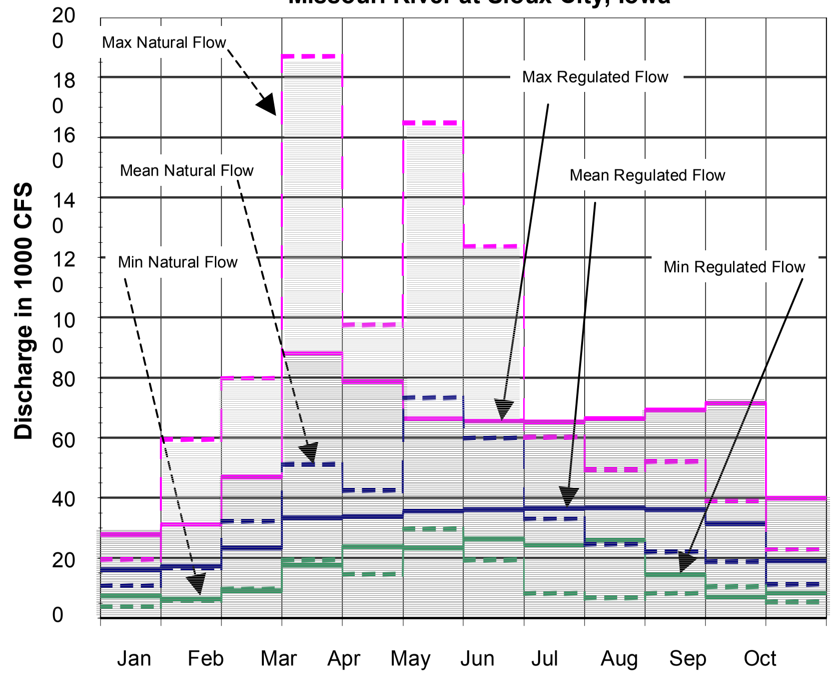
Missouri River Basin Generalized Estimates of Mean Annual Runoff in Inches

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Notes:

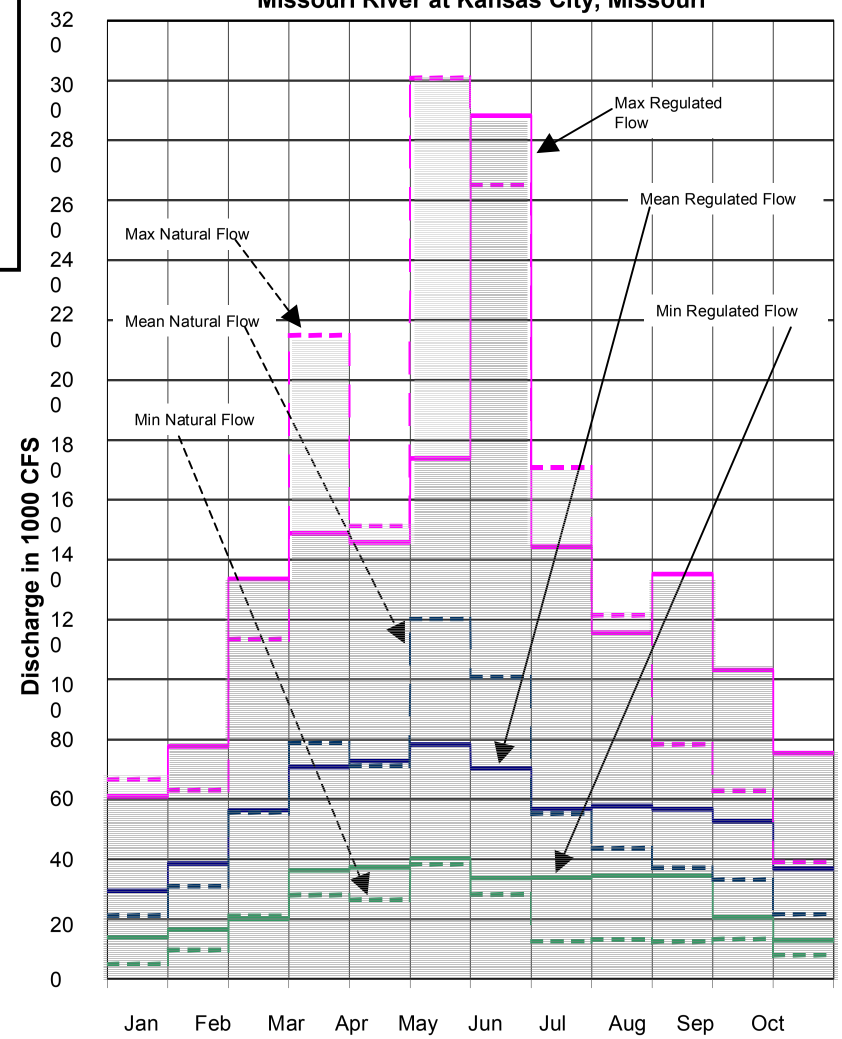
1. Natural flows refer to Missouri River flows prior to 1953.
2. Regulated flows refer to Missouri River flows from 1953 to present.
3. Natural flows are from historical data presented in Missouri River Inter-Agency Committee Report - 1959 Adequacy of Flows in the Missouri River for 1898-1952.
4. Regulated flows are from USGS measured flows as reported in the 2002 Water Supply Reports (Iowa and Missouri).

Missouri River at Sioux City, Iowa



Max Natural	1919	1928	1910	1952	1927	1927	1909	1923	1951	1923	1951	1923
Max Regulated	1987	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997	1997
Min Natural	1940	1940	1940	1931	1931	1940	1934	1919	1919	1921	1935	1937
Min Regulated	1964	1963	1957	1957	1962	1960	2002	1993	1962	1961	1961	1961

Missouri River at Kansas City, Missouri



Max Natural	1910	1916	1949	1952	1920	1908	1915	1915	1951	1941	1951	1909
Max Regulated	1973	1973	1979	1984	1995	1984	1993	1993	1993	1973	1998	1986
Min Natural	1940	1940	1940	1934	1934	1934	1934	1934	1934	1939	1936	1937
Min Regulated	1963	1964	1964	1990	1989	1989	2002	1991	1991	1991	1990	1963

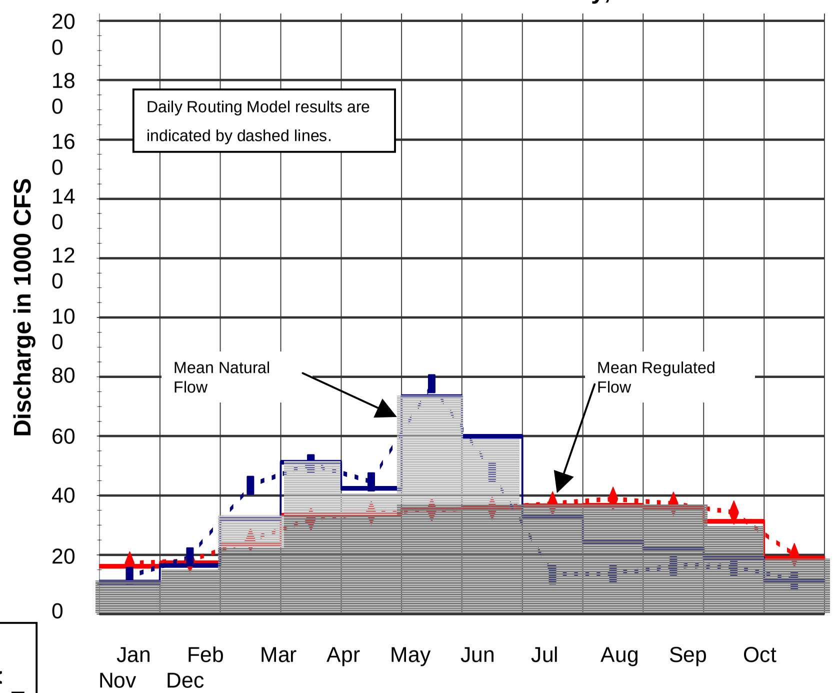
Missouri River Basin
Monthly Streamflow Distribution

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

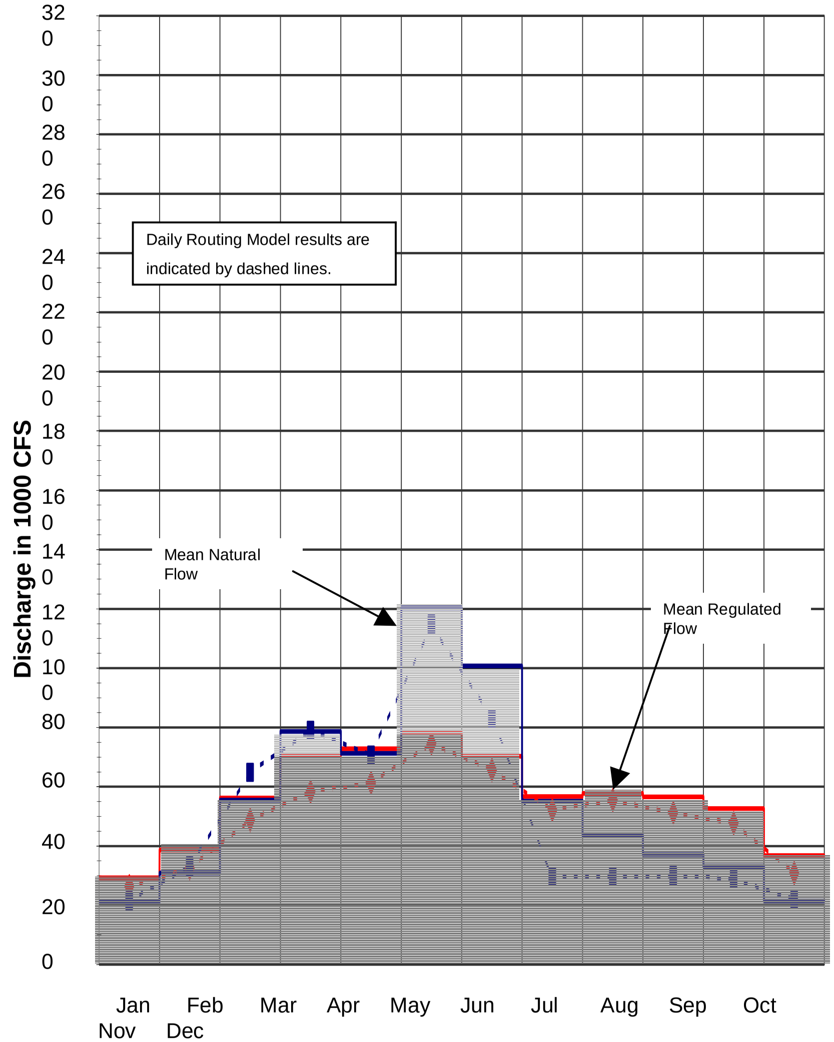
Notes:

1. Natural flows refer to Missouri River flows prior to 1953.
2. Regulated flows refer to Missouri River flows from 1953 to present.
3. Natural flows are from historical data presented in Missouri River Inter-Agency Committee Report - 1959 Adequacy of Flows in the Missouri River for 1898-1952.
4. Regulated flows are from USGS measured flows as reported in the 2002 Water Supply Reports (Iowa and Missouri).
5. Daily Routing Model flows encompass a 100-year period from 1898-1997.

Missouri River at Sioux City, Iowa



Missouri River at Kansas City, Missouri

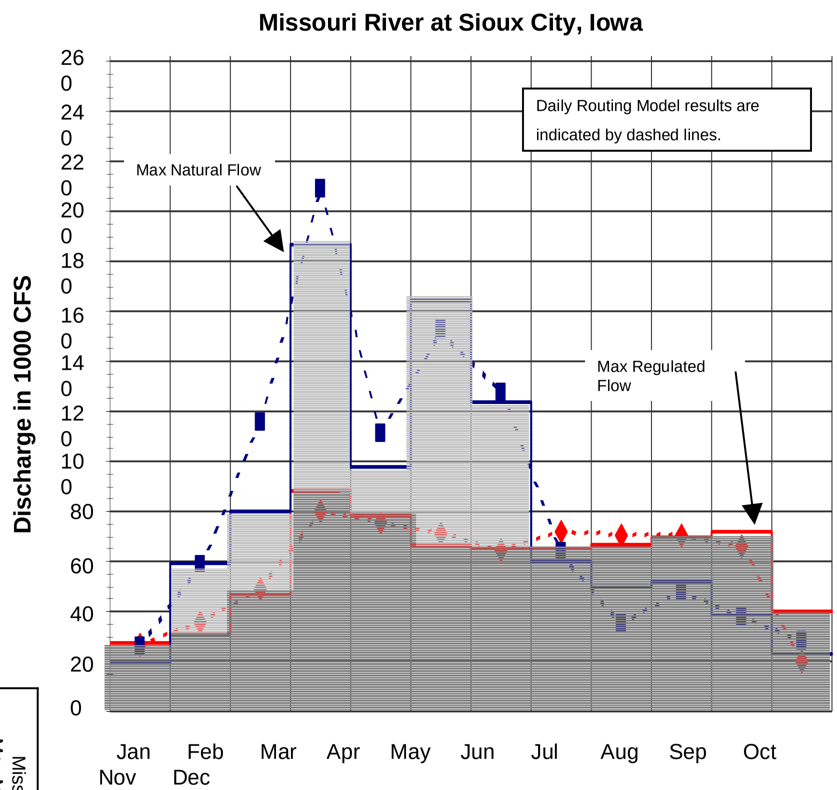


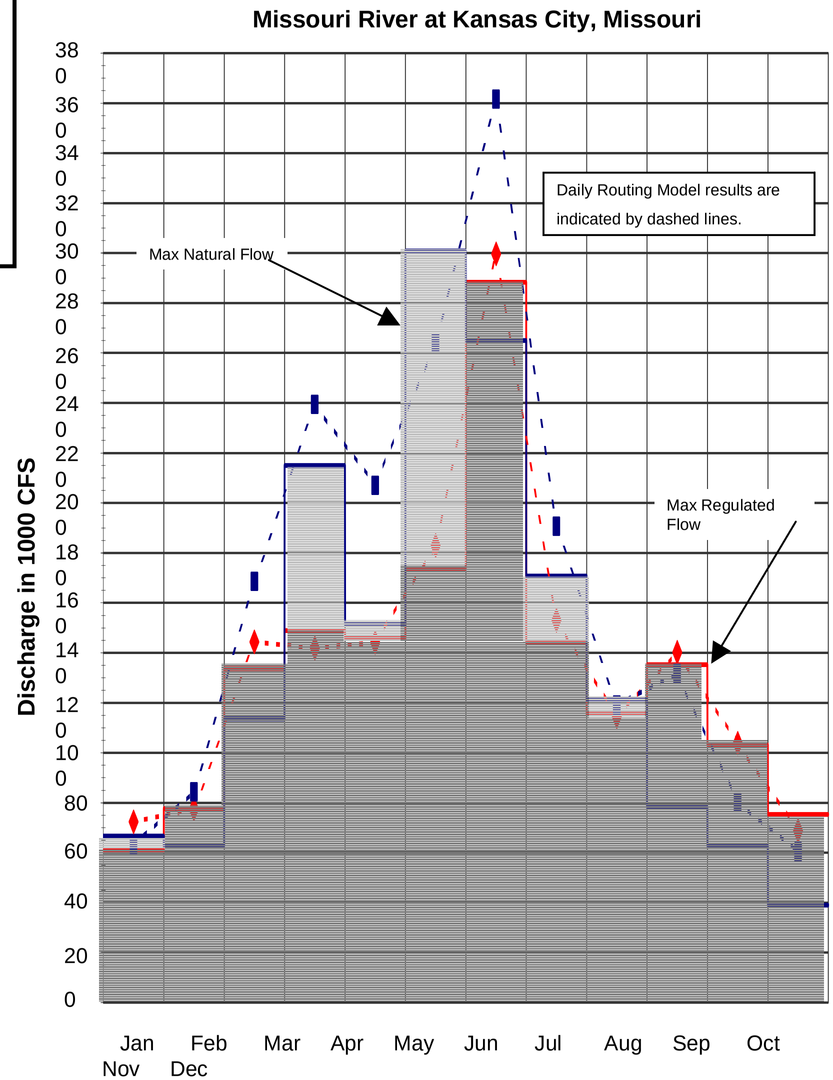
Missouri River Basin
Mean Monthly Streamflow
Distribution Comparison to DRM Results

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003

Notes:

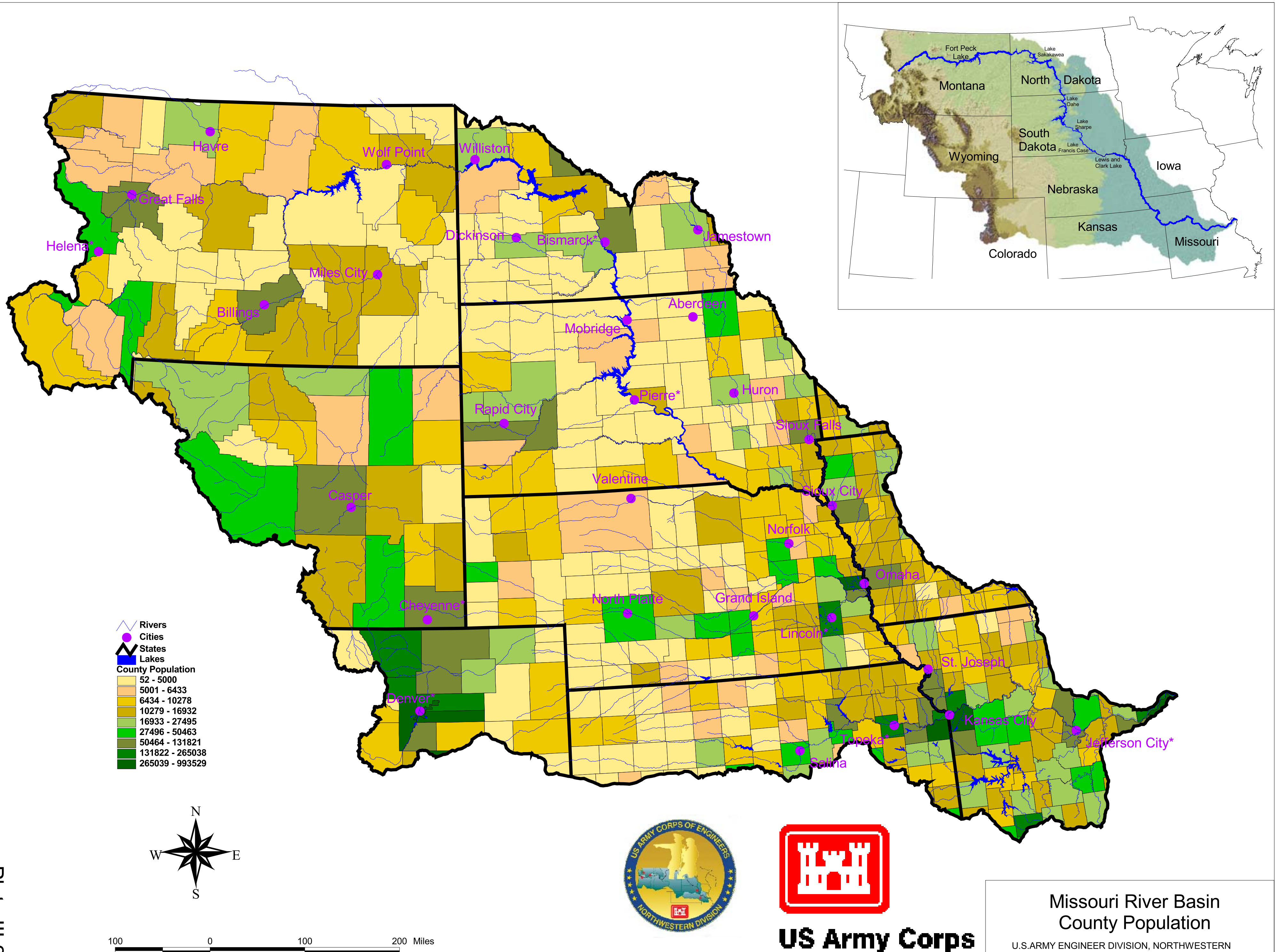
1. Natural flows refer to Missouri River flows prior to 1953.
2. Regulated flows refer to Missouri River flows from 1953 to present.
3. Natural flows are from historical data presented in Missouri River Inter-Agency Committee Report - 1959 Adequacy of Flows in the Missouri River for 1898-1952.
4. Regulated flows are from USGS measured flows as reported in the 2002 Water Supply Reports (Iowa and Missouri).
5. Daily Routing Model flows encompass a 100-year period from 1898-1997.





Missouri River Basin
Max Monthly Streamflow
Distribution Comparison to DRM
Results

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003

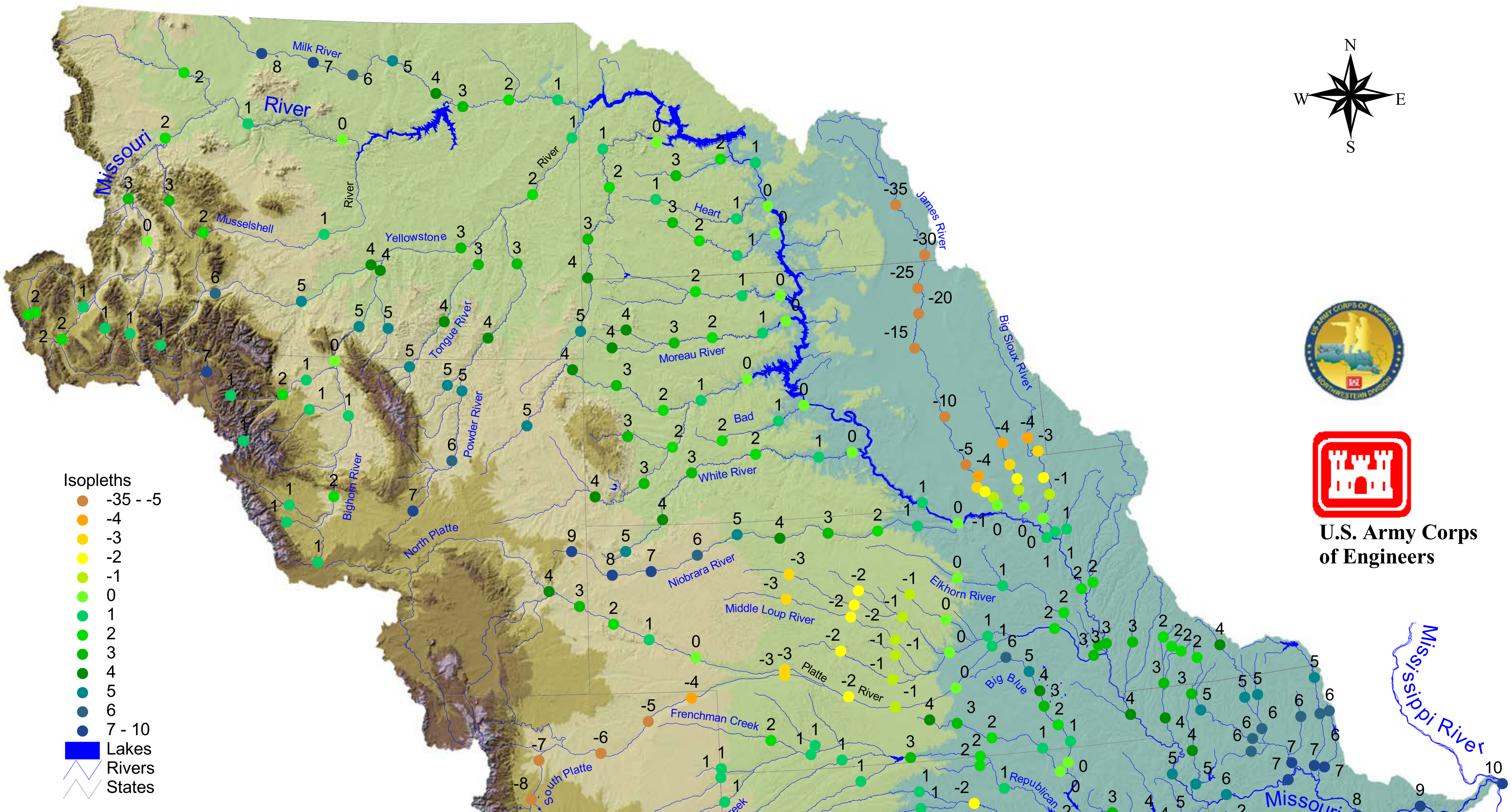


US Army Corps of Engineers®

Missouri River Basin County Population

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate III-28



NOTES:

1. Isopleths above reservoirs indicate travel time in days to the reservoir
2. All other isopleths indicate coincidence with releases made from Gavins Point Reservoir the give number of days earlier. Negative isopleths indicated coincidence with releases to be made the given number of days later.
3. Based on average travel time of moderate rise at or near bankfull levels.

At Bankfull - Travel Time in days

Miles/Day

84	120	120	120	120	120	120	120	120	
GAPT									
1	SUX								
2	1	OMA							
2	1	0	NCNE						
3	2	1	1	STJ					
4	3	2	2	1	MKC				
5	4	3	2	1	1	WVMO			
5	4	3	3	2	1	1	BNMO		
6	5	4	4	3	2	2	1	HEMO	
7	6	5	5	4	3	2	2	1	STL

At Navigation Flows - Travel Time in days

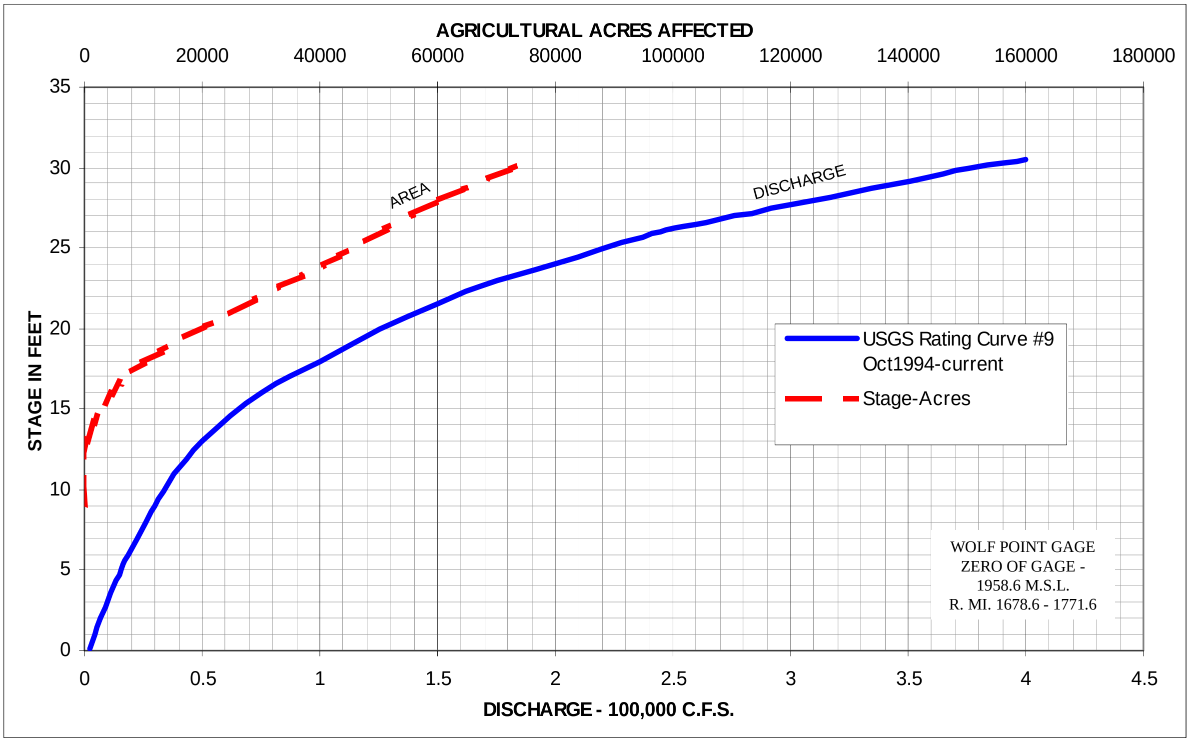
Miles/Day

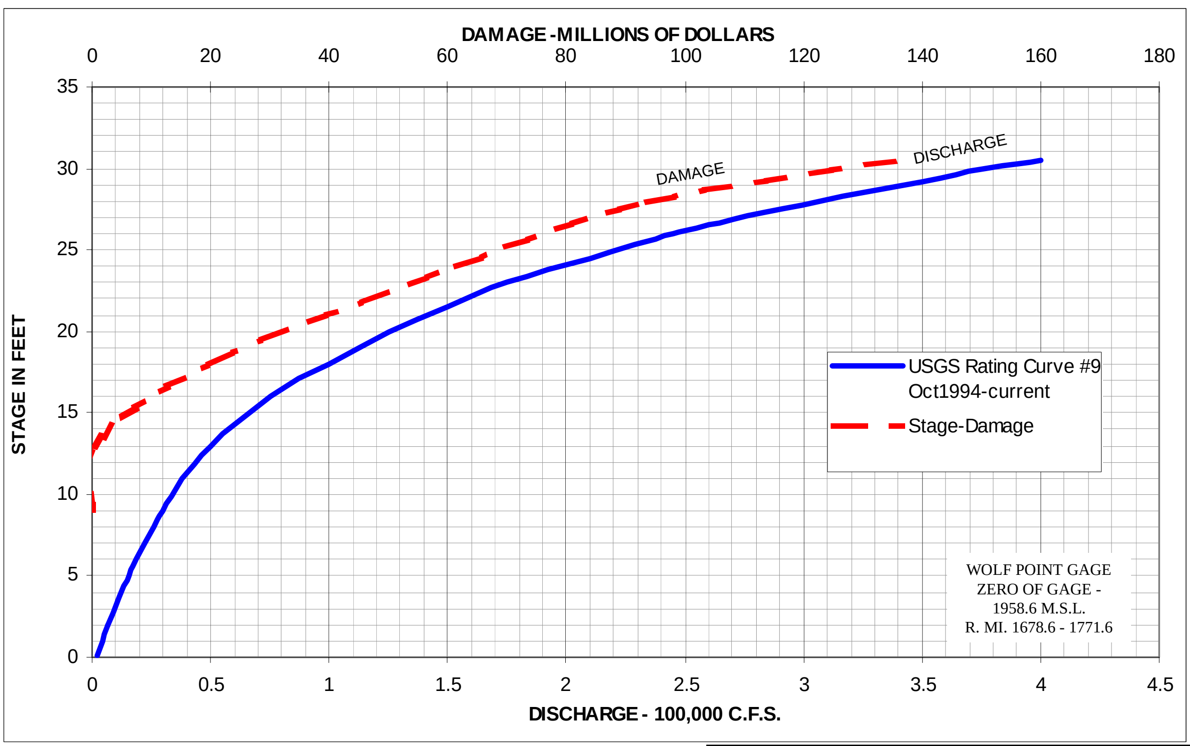
56	80	80	80	80	80	80	80	80	
GAPT									
1	SUX								
3	1	OMA							
4	2	1	NCNE						
5	4	2	1	STJ					
6	5	3	2	1	MKC				
7	5	4	3	2	1	WVMO			
8	7	5	5	3	2	1	BNMO		
9	8	6	6	4	3	2	1	HEMO	
11	9	8	7	6	5	4	2	1	STL

Missouri River Basin Water Travel Time

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-1



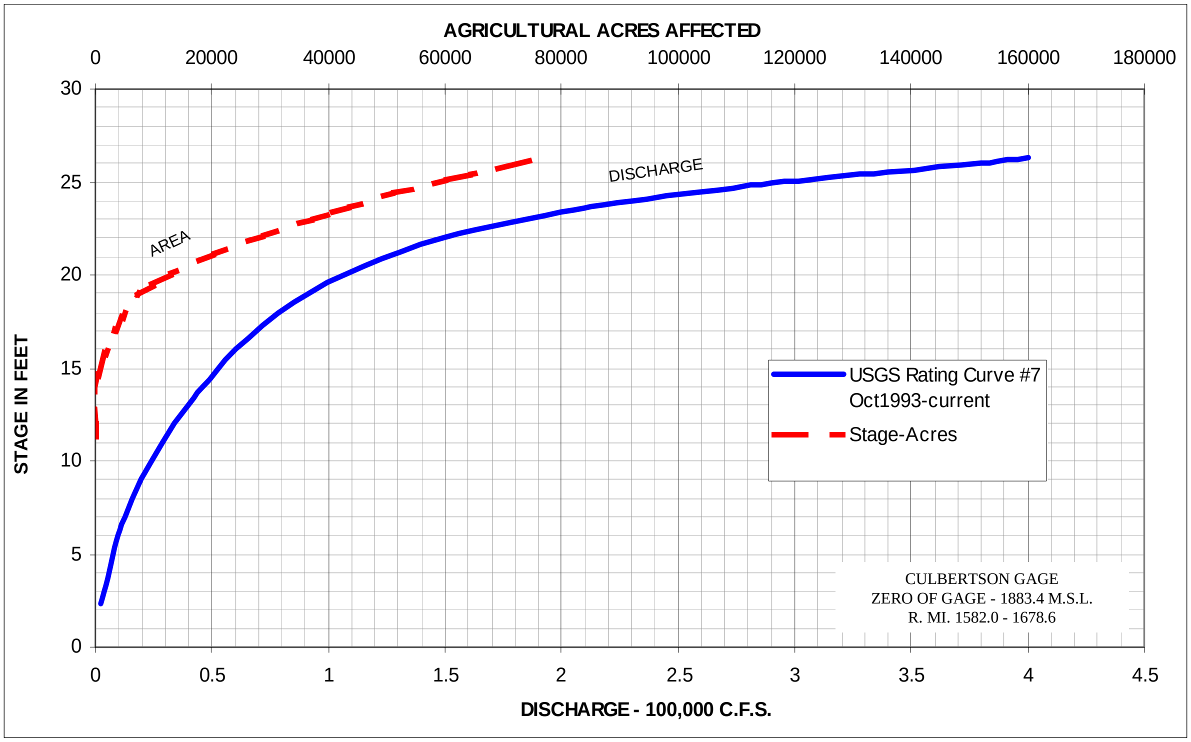


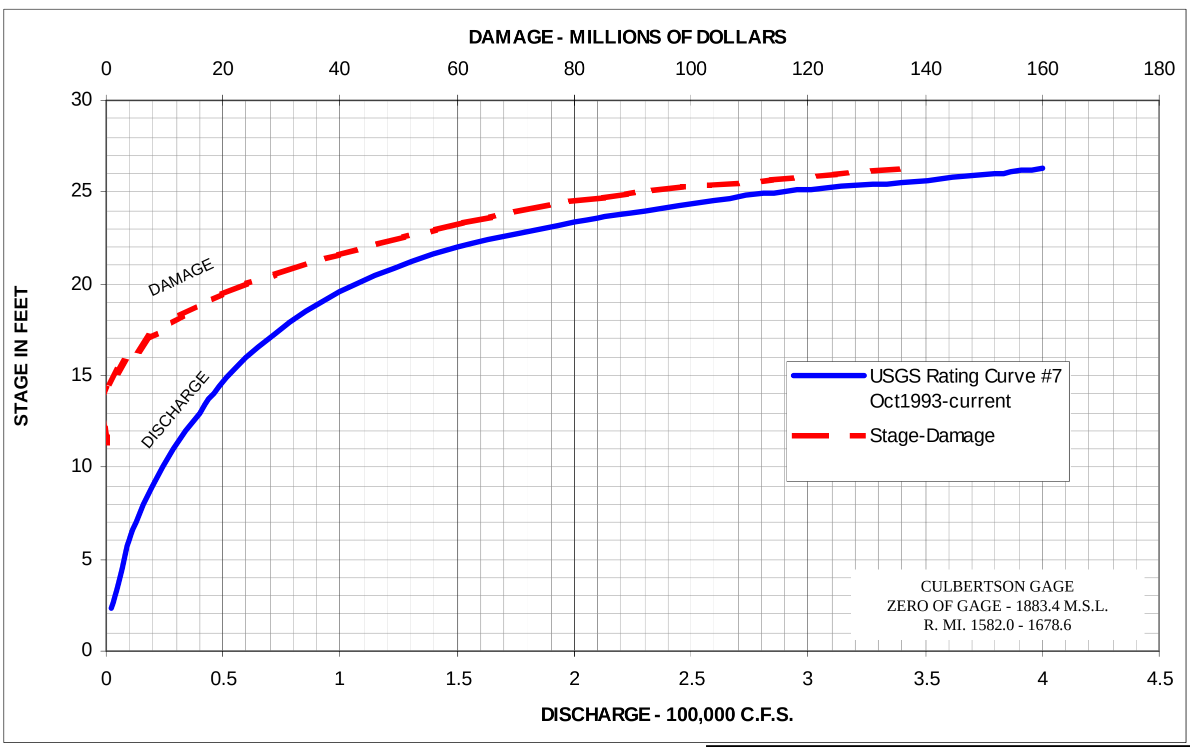
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-2



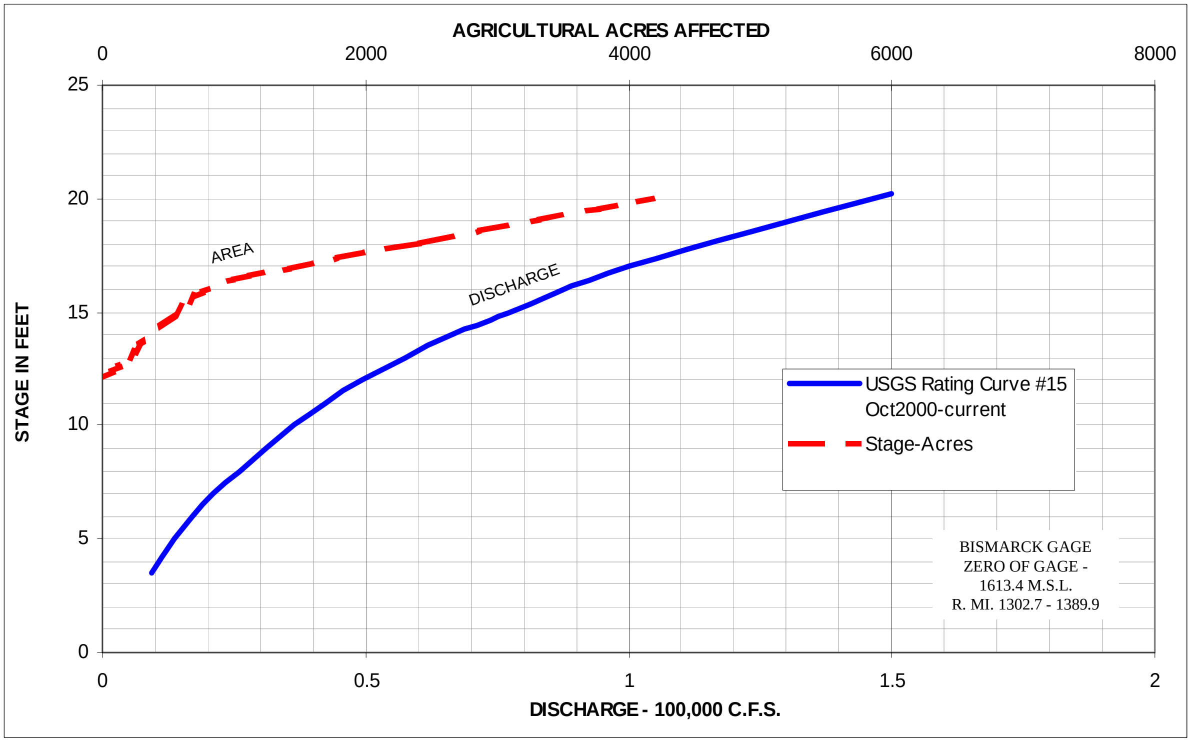


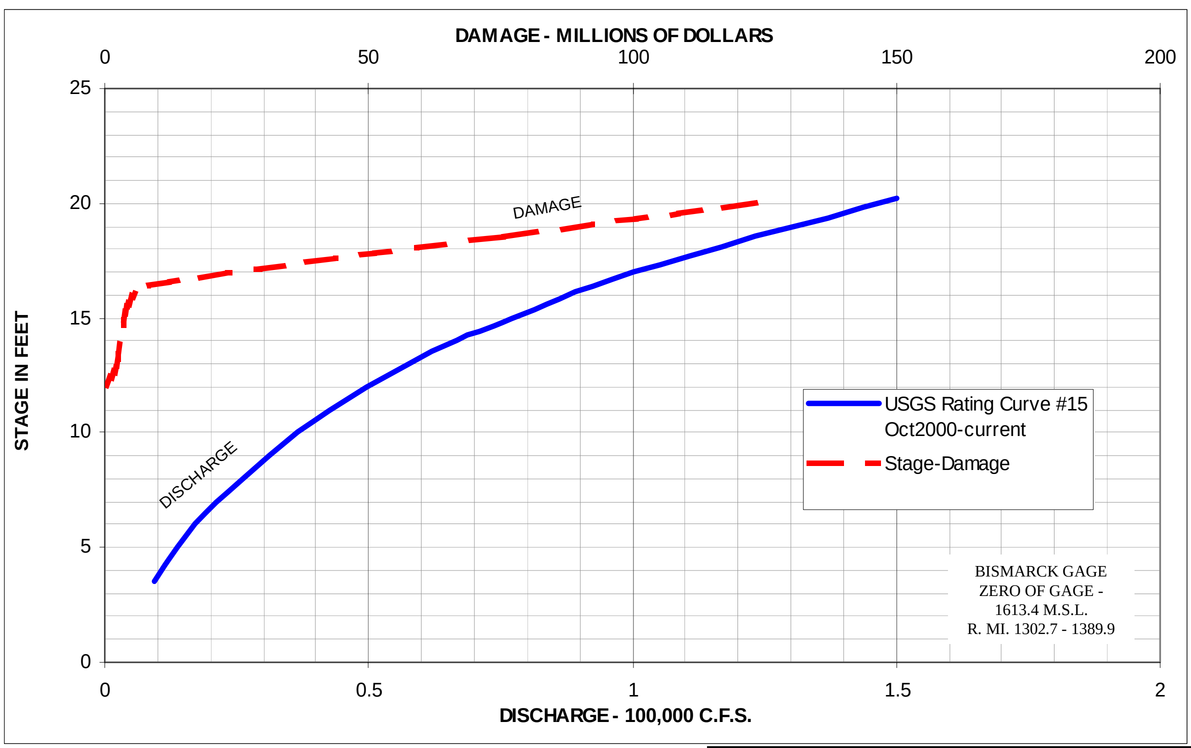
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-3



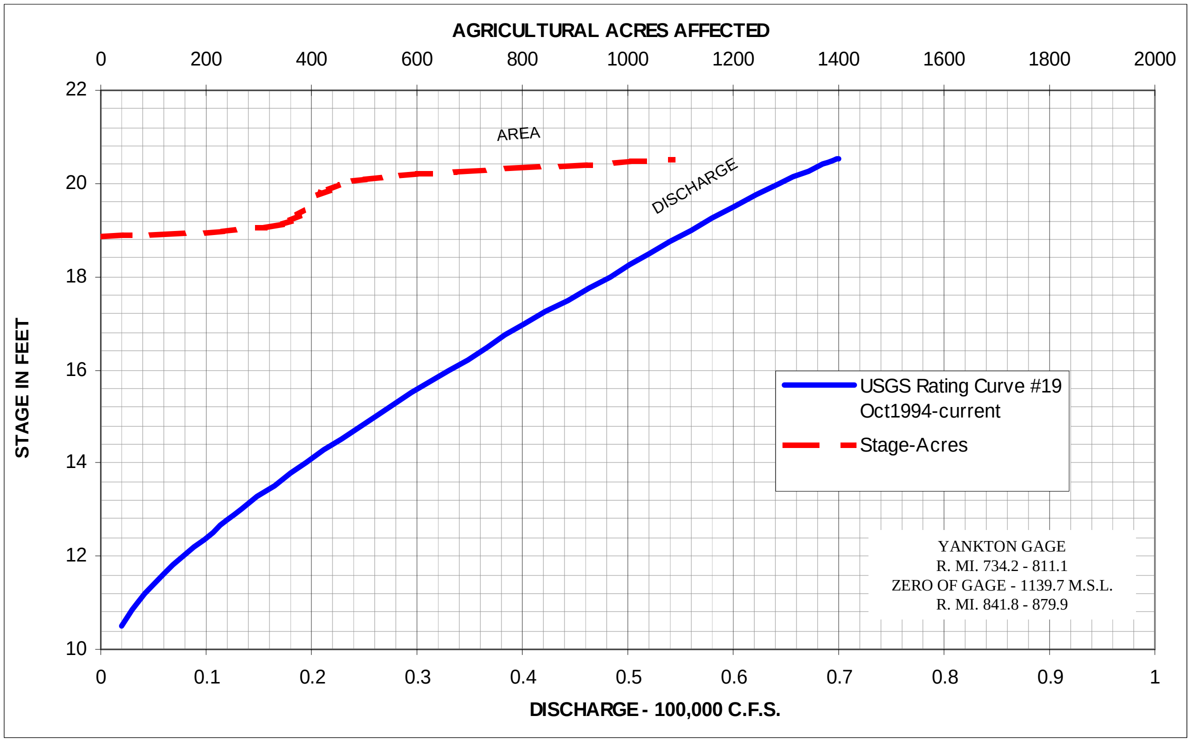


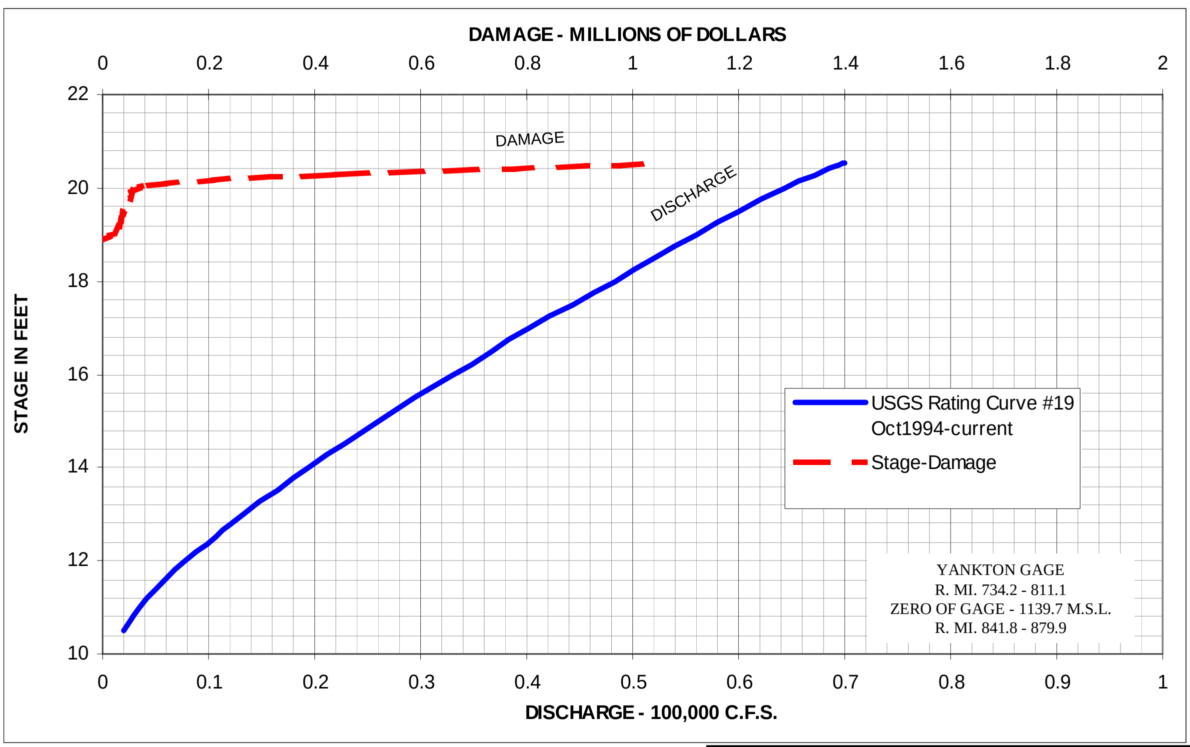
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-4



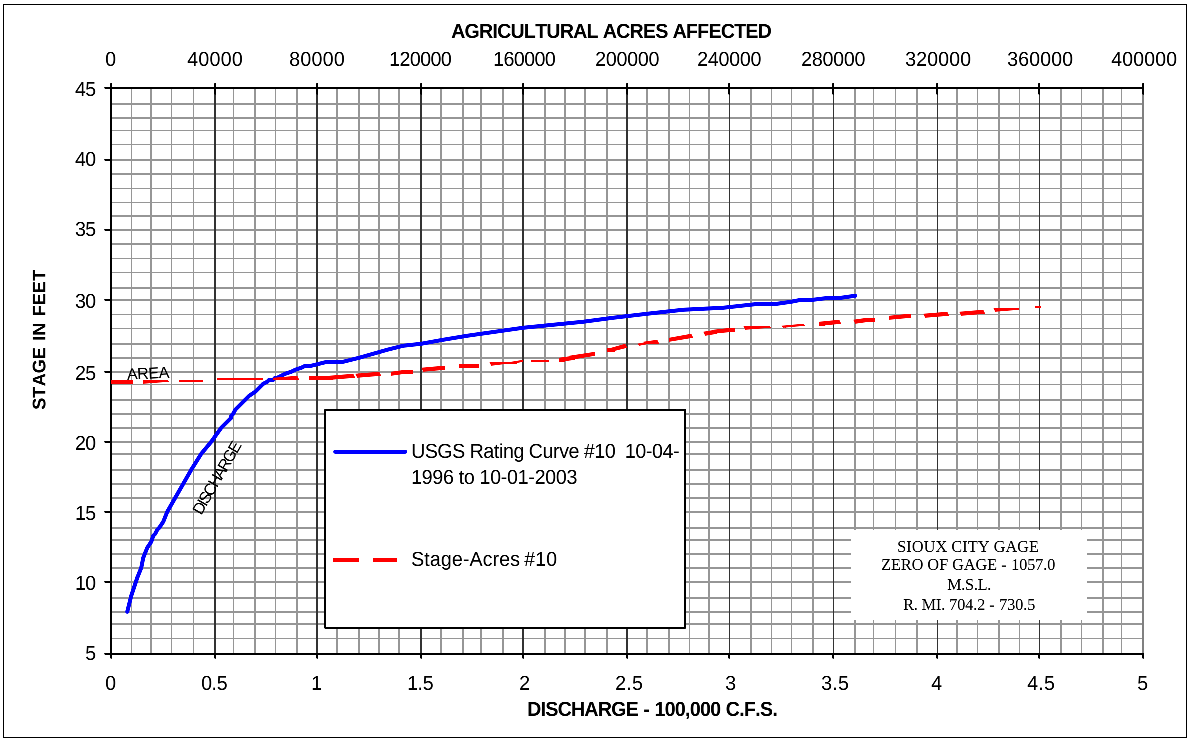


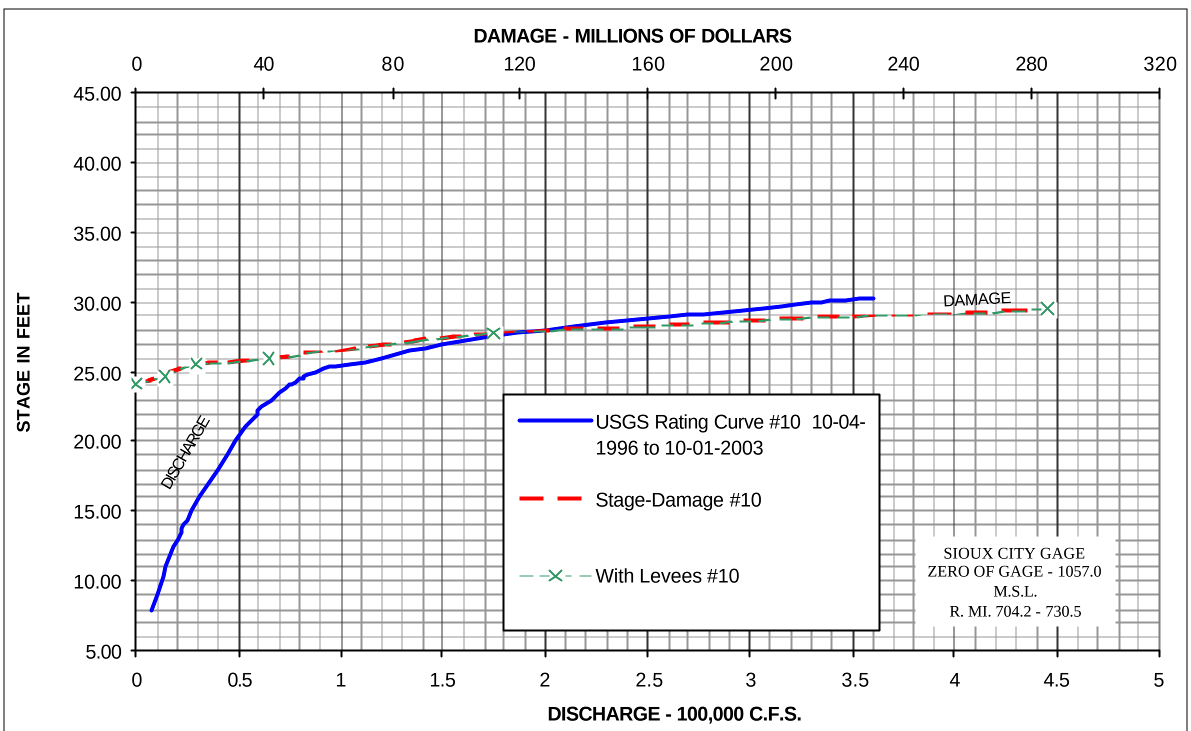
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-5



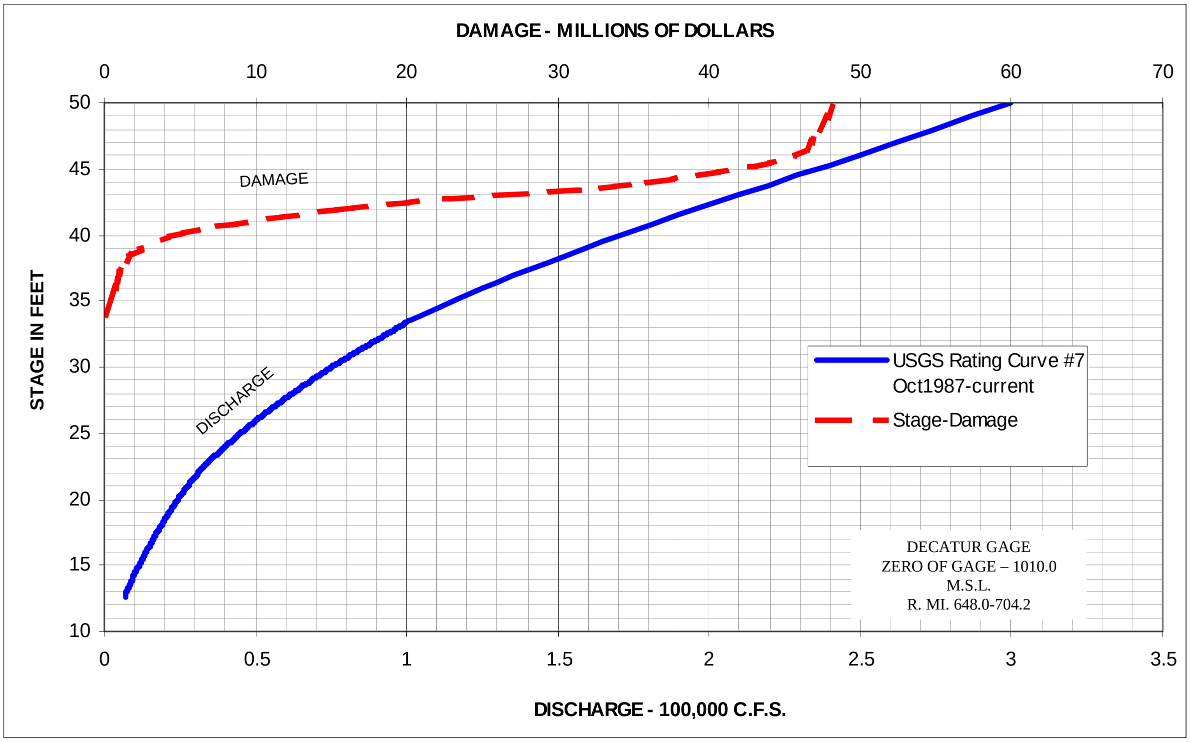


NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-6

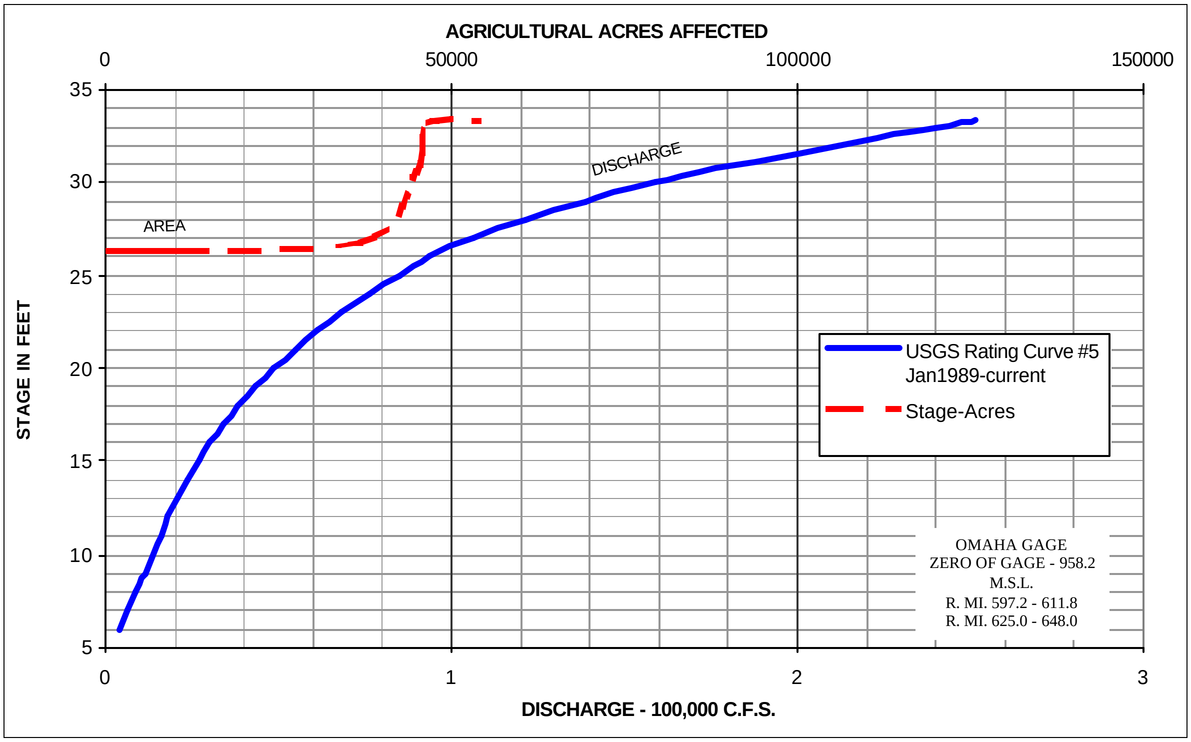


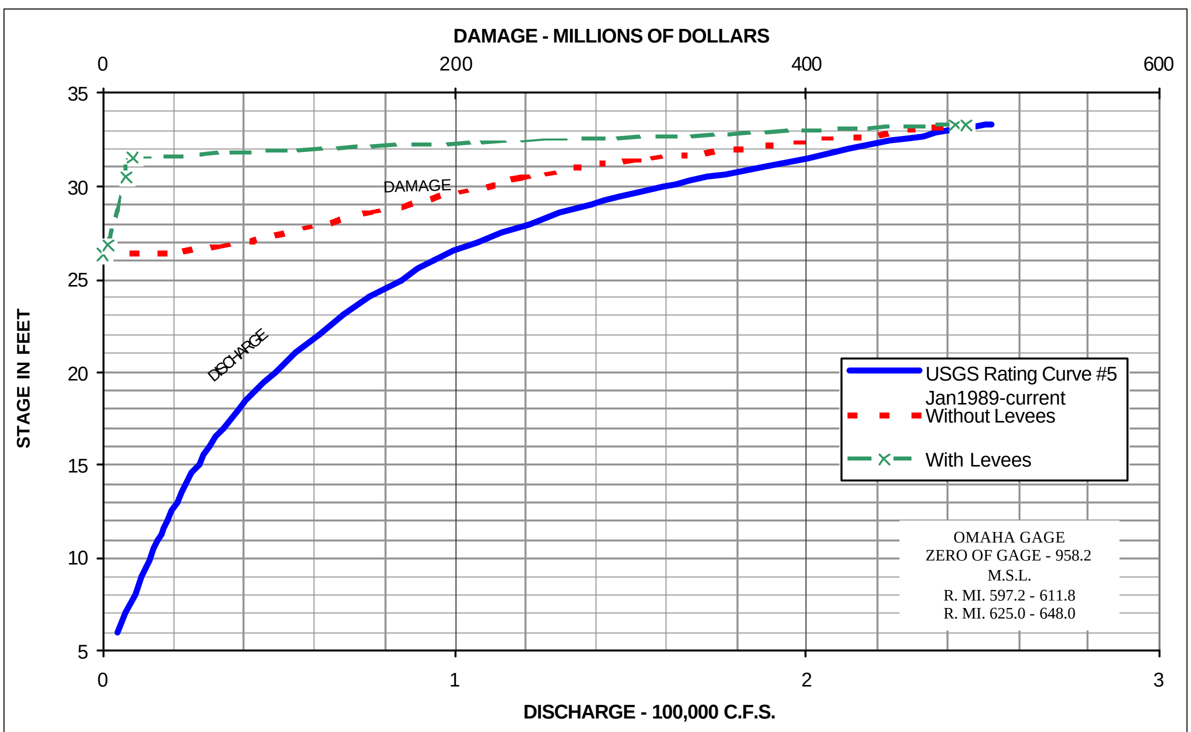
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-7



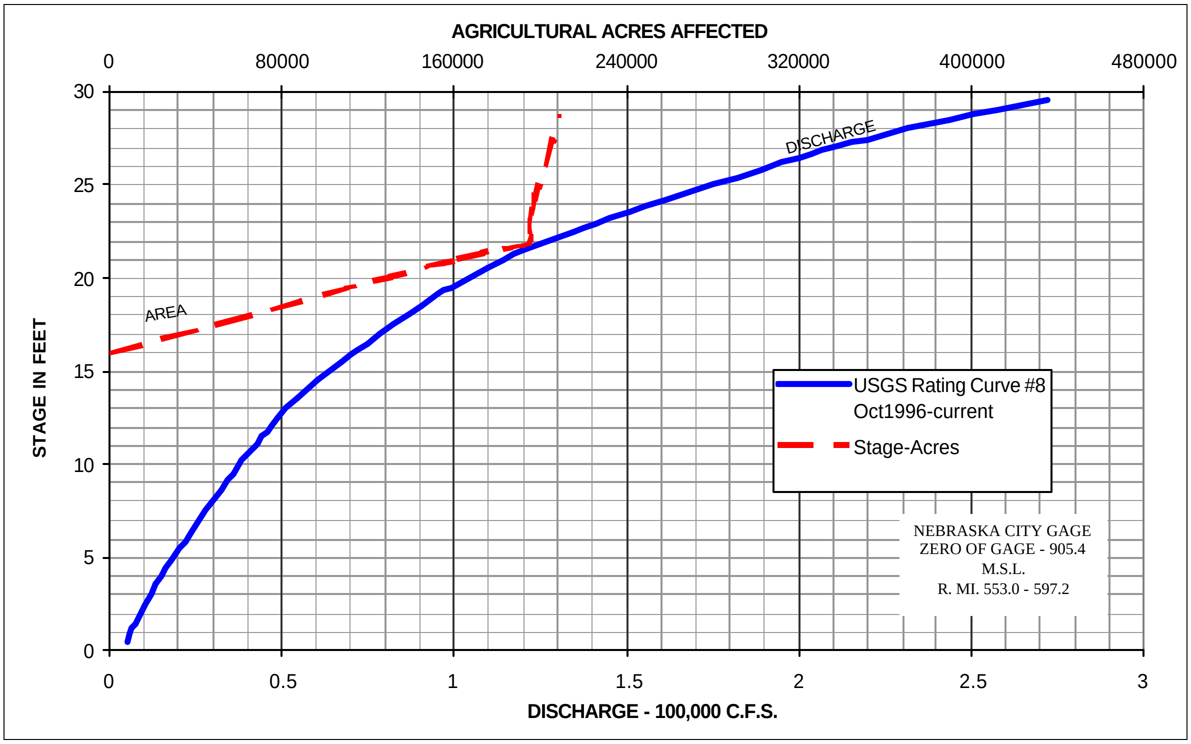


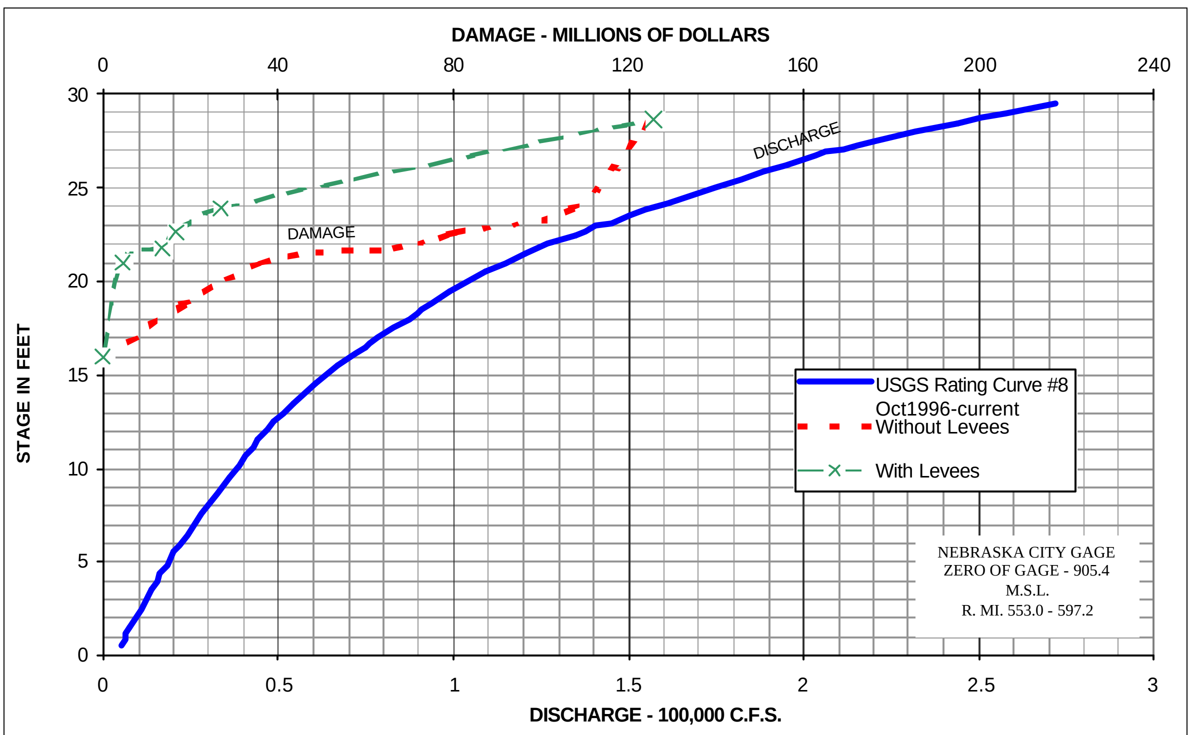
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-8



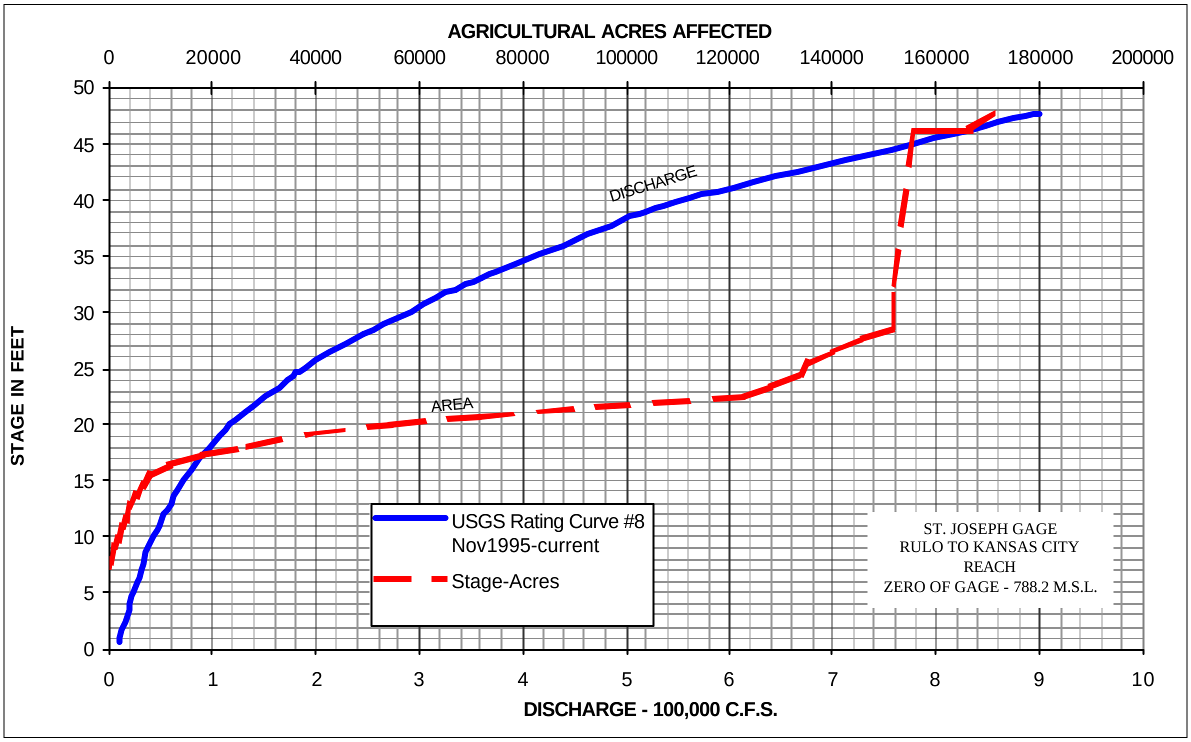


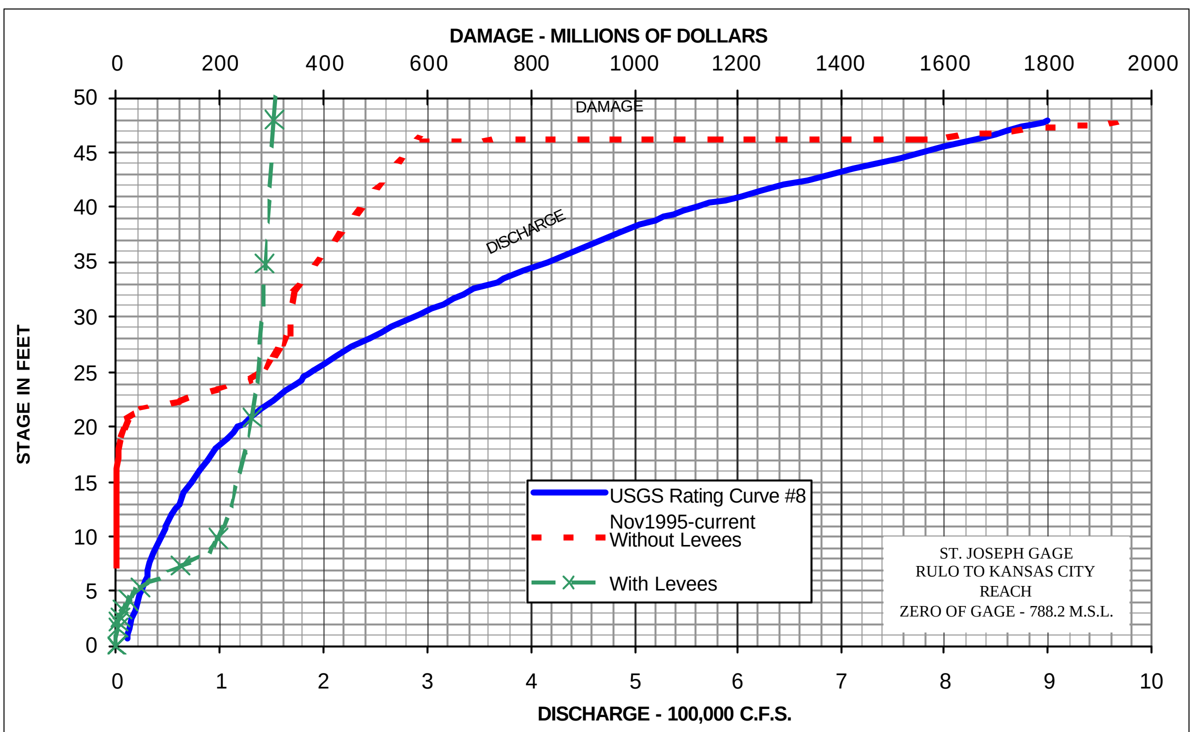
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-9



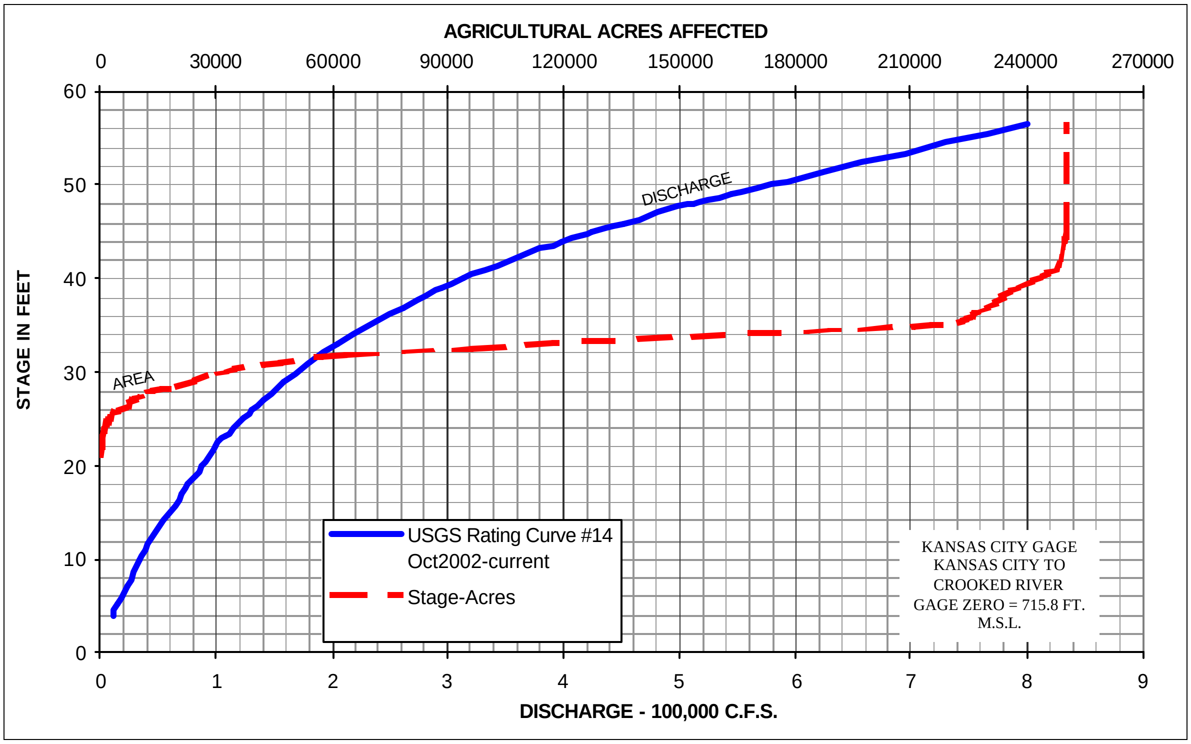


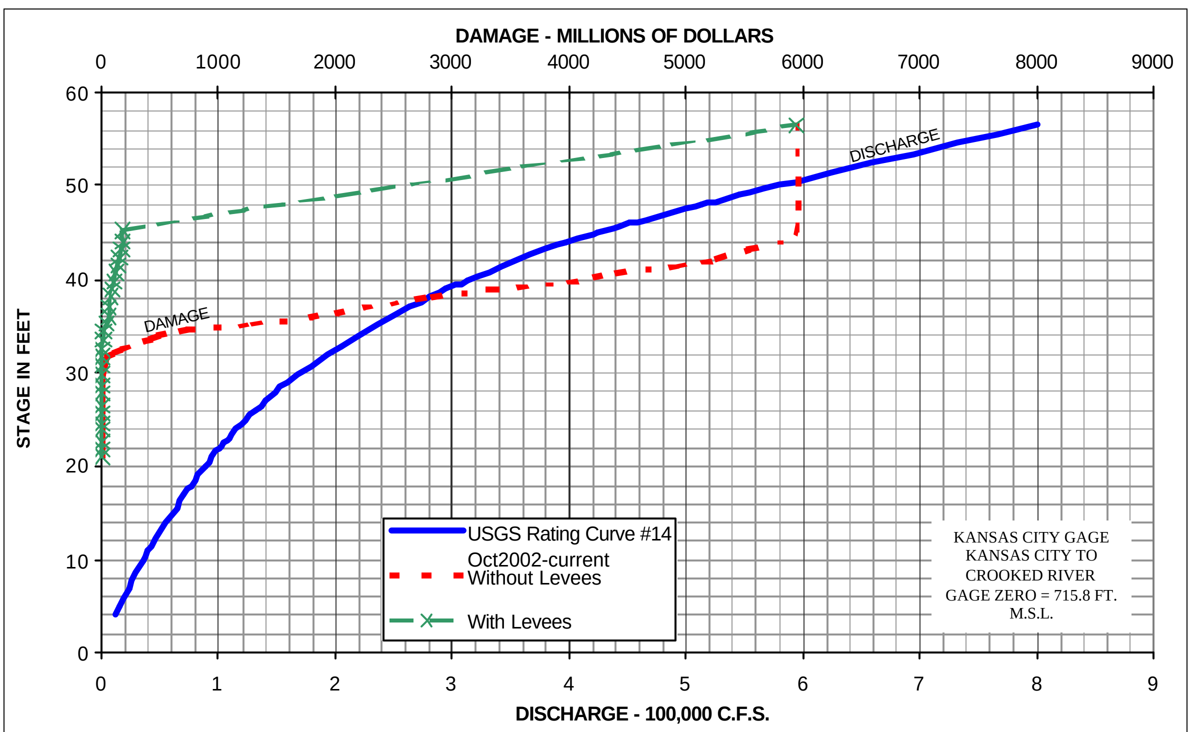
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-10



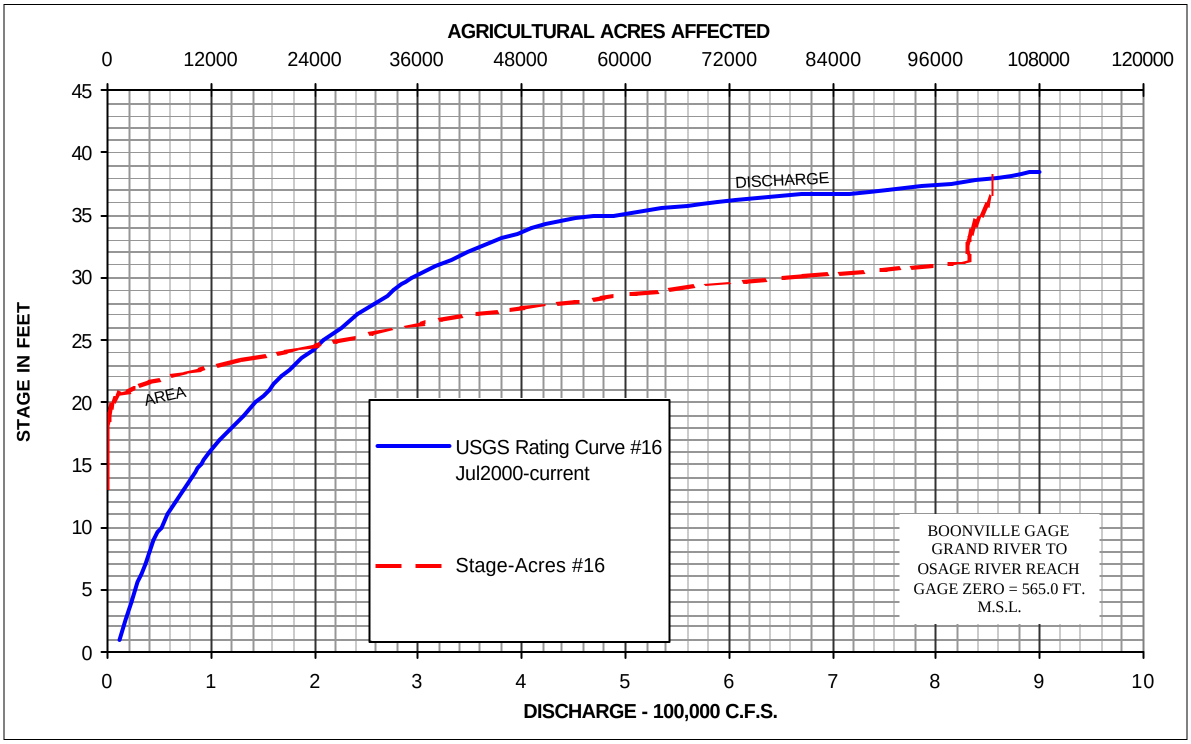


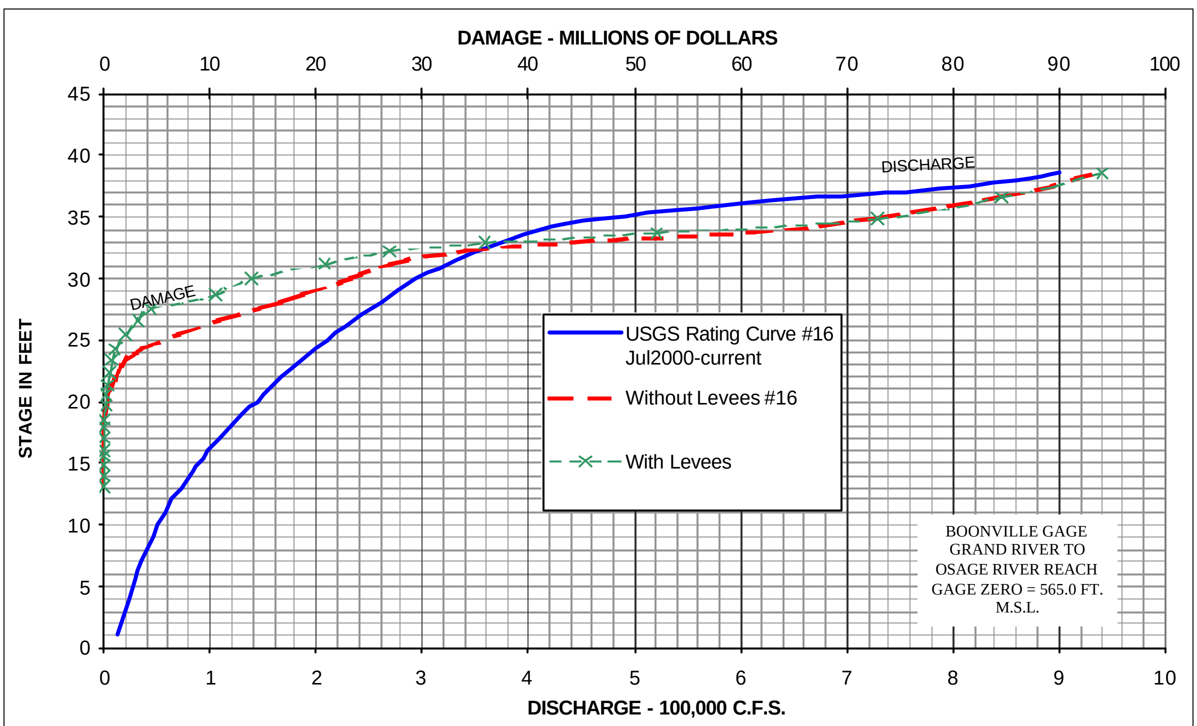
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-11



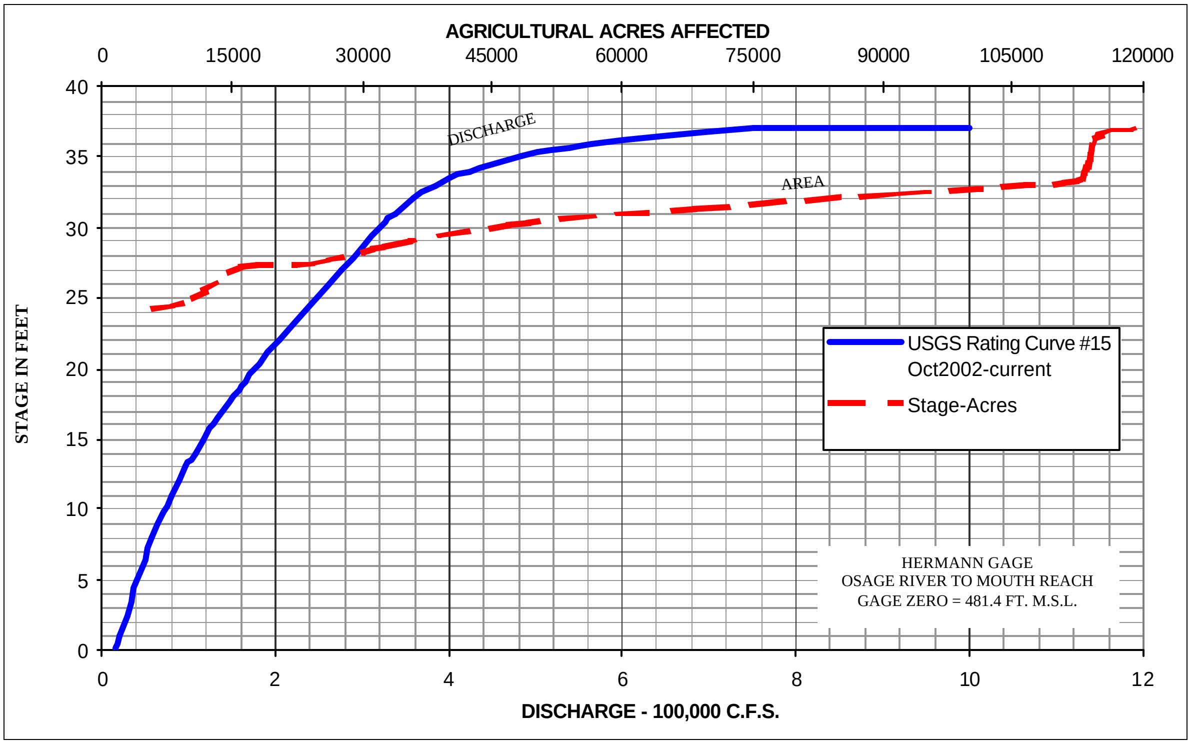


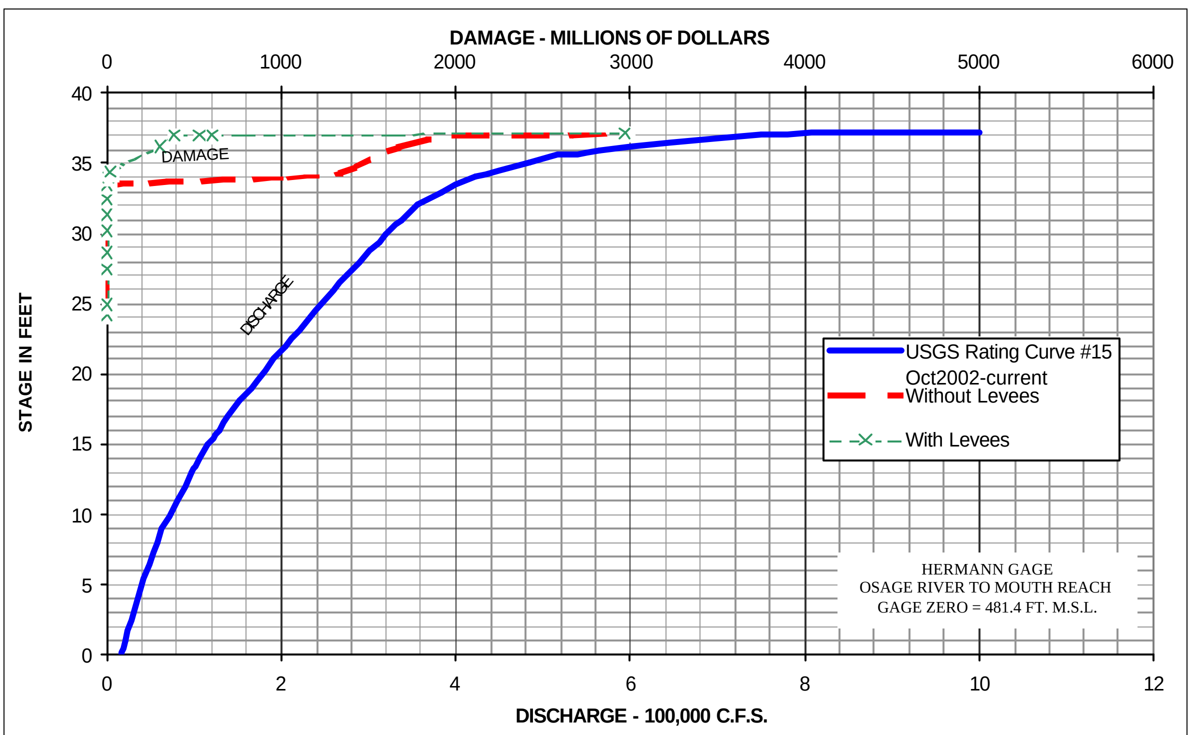
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-12





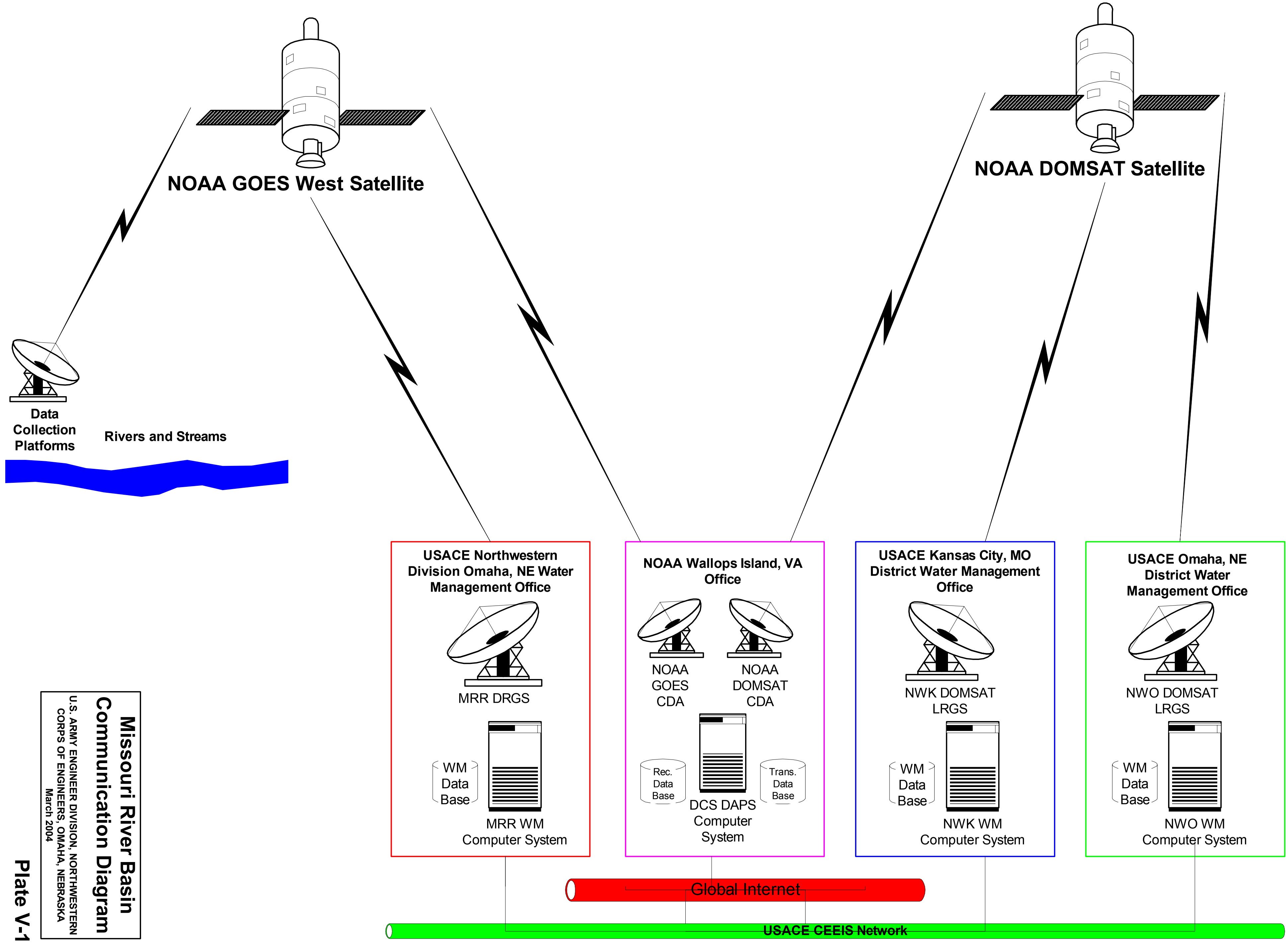
NOTE: Damage curves are based on 1996 land use surveys. Rating curves are based on current USGS streamflow measurements.

Missouri River Basin
Stage-Discharge-Area-Damage Curves

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate IV-13

Missouri River Data Collection System



Missouri River Basin Communication Diagram

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate V-1

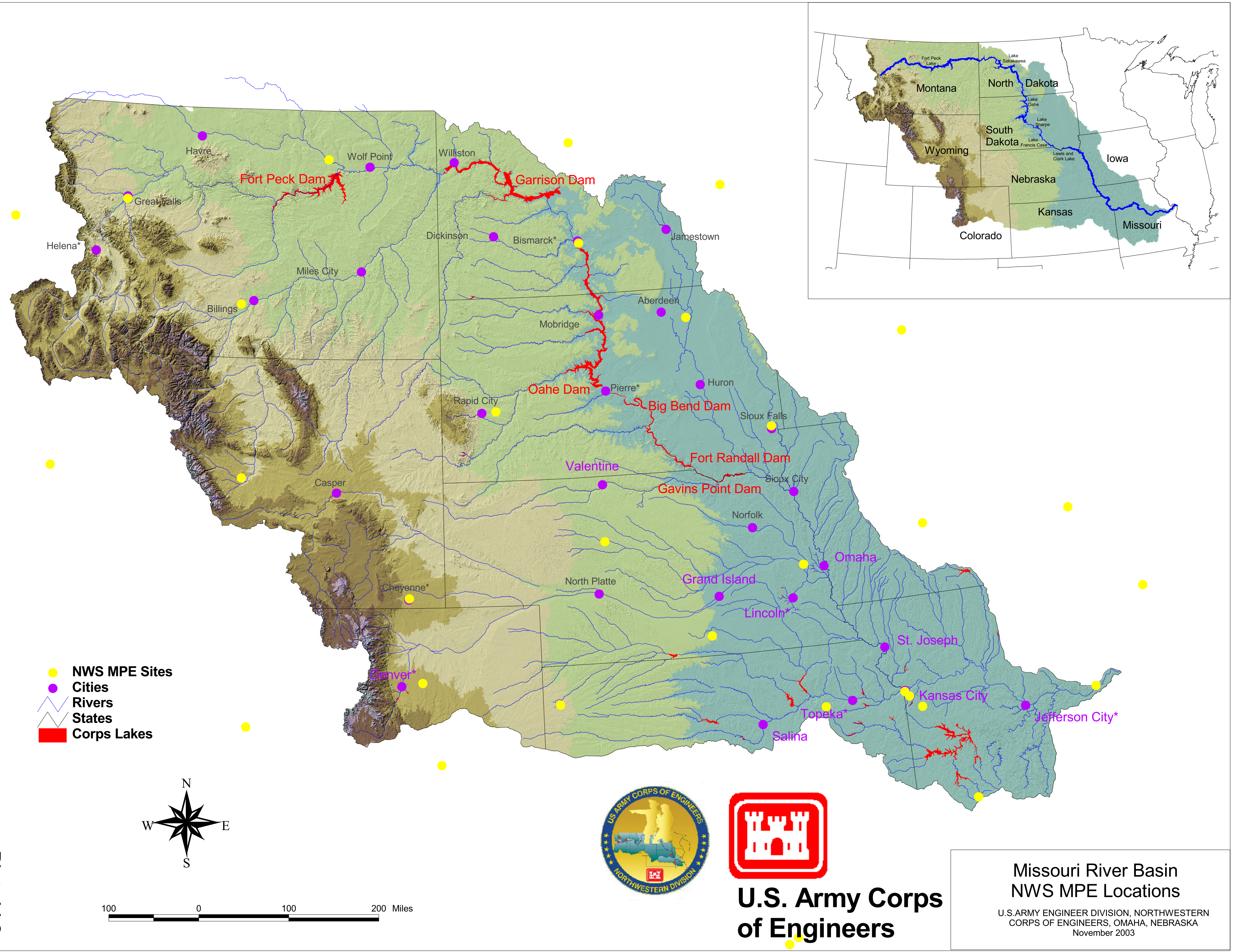
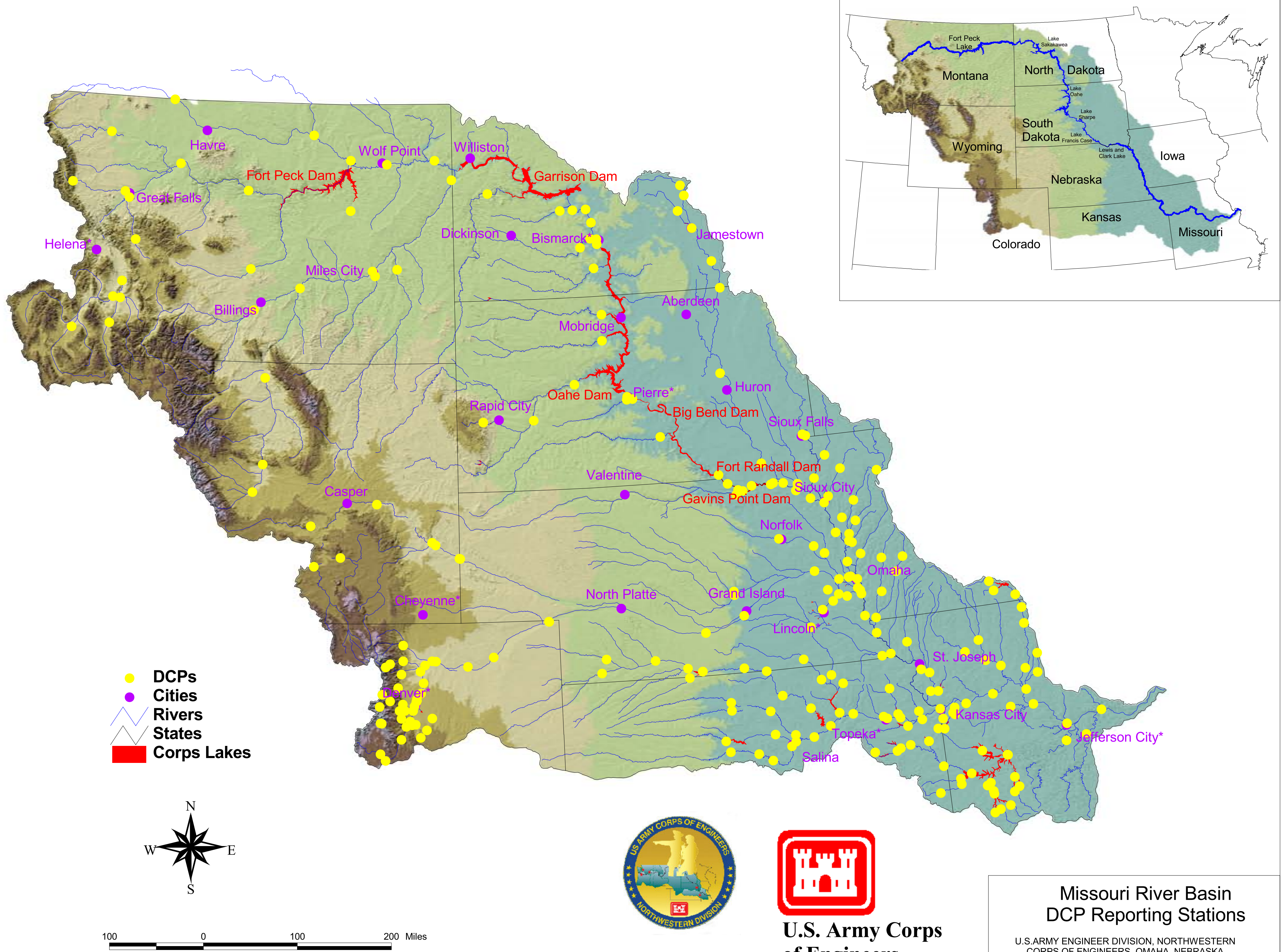


Plate V-2

Missouri River Basin
NWS MPE Locations

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003



U.S. Army Corps of Engineers

Missouri River Basin DCP Reporting Stations

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003

Plate V-3

MONTHLY RESERVOIR OPERATION

RESERVOIR	RIVER	DISTRICT
FORT PECK	MISSOURI RIVER	OMAHA

MISSOURI RIVER REGION — U.S. ARMY CORPS OF ENGINEERS

JAN. 2004	ELEV. MSL	PAN INCH	EVAP. CFS	MEAN DISCHARGE IN CFS OUTFLOW POWER	SPILL		INFLOW	
1	2206.80+		200-	9,000	0+		5,000	
2	2206.72		200	9,000	0		5,000	
3	2206.63		200	8,800	0		3,000	
4	2206.54		200	8,800	0		2,000-	
5	2206.54		200	8,700	0		3,000	
6	2206.54		200	8,500-	0		3,000	
7	2206.54		200	8,600	0		3,000	
8	2206.19		200	8,800	0		3,000	
9	2206.05		200	8,900	0		2,000	
10	2206.02		200	8,800	0		2,000	
11	2205.97		200	8,800	0		3,000	
12	2205.92		200	9,000	0		5,000	
13	2205.85		200	9,000	0		5,000	
14	2205.80		200	8,600	0		5,000	
15	2205.79		200	8,800	0		5,000	
16	2205.79		200	9,000	0		6,000	
17	2205.70		200	9,200	0		6,000	
18	2205.66		200	9,400+	0		6,000	
19	2205.61		200	9,100	0		6,000	
20	2205.61		300+	9,100	0		7,000+	
21	2205.56		300	9,100	0		7,000	
22	2205.55		300	8,900	0		7,000	
23	2205.49		300	9,000	0		7,000	
24	2205.50		300	8,800	0		7,000	
25	2205.47		300	9,000	0		7,000	
26	2205.41		300	9,100	0		7,000	
27	2205.43		300	8,900	0		7,000	
28	2205.40		300	8,900	0		7,000	
29	2205.32		300	8,900	0		6,000	
30	2205.29-		300	8,800	0		7,000	
31	2205.29		300	8,800	0		7,000	
TOTAL	(DSF)	0.00	7400	276,100	0	0	161,000	0
TOTAL	(AC-FT)		15000	548,000	0	0	319,000	0
MEAN	2205.87	0.00	200	8,900	0	0	5,200	0

REMARKS - RESERVOIR STORAGE EOM = 9806000 CHNG = -243000

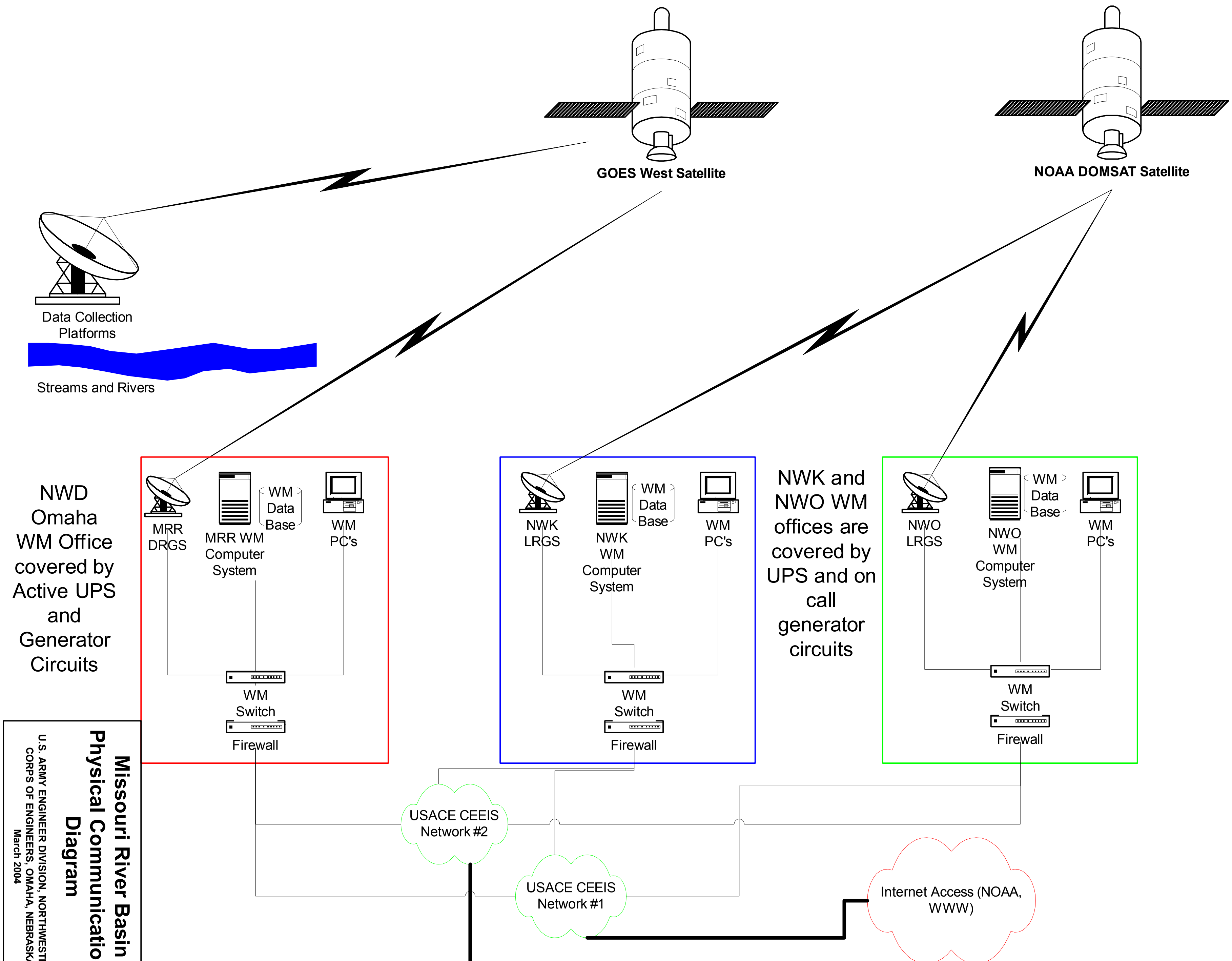
+ MAX. MONTHLY MAX = 10040000 (1) MIN = 9806000 (31)

- MIN. MONTHLY PRECIP. = 0.68 INCHES

NOTE: Lake Frozen Over 8 Jan 04 — JAN. 2004

PROVISIONAL RECORD

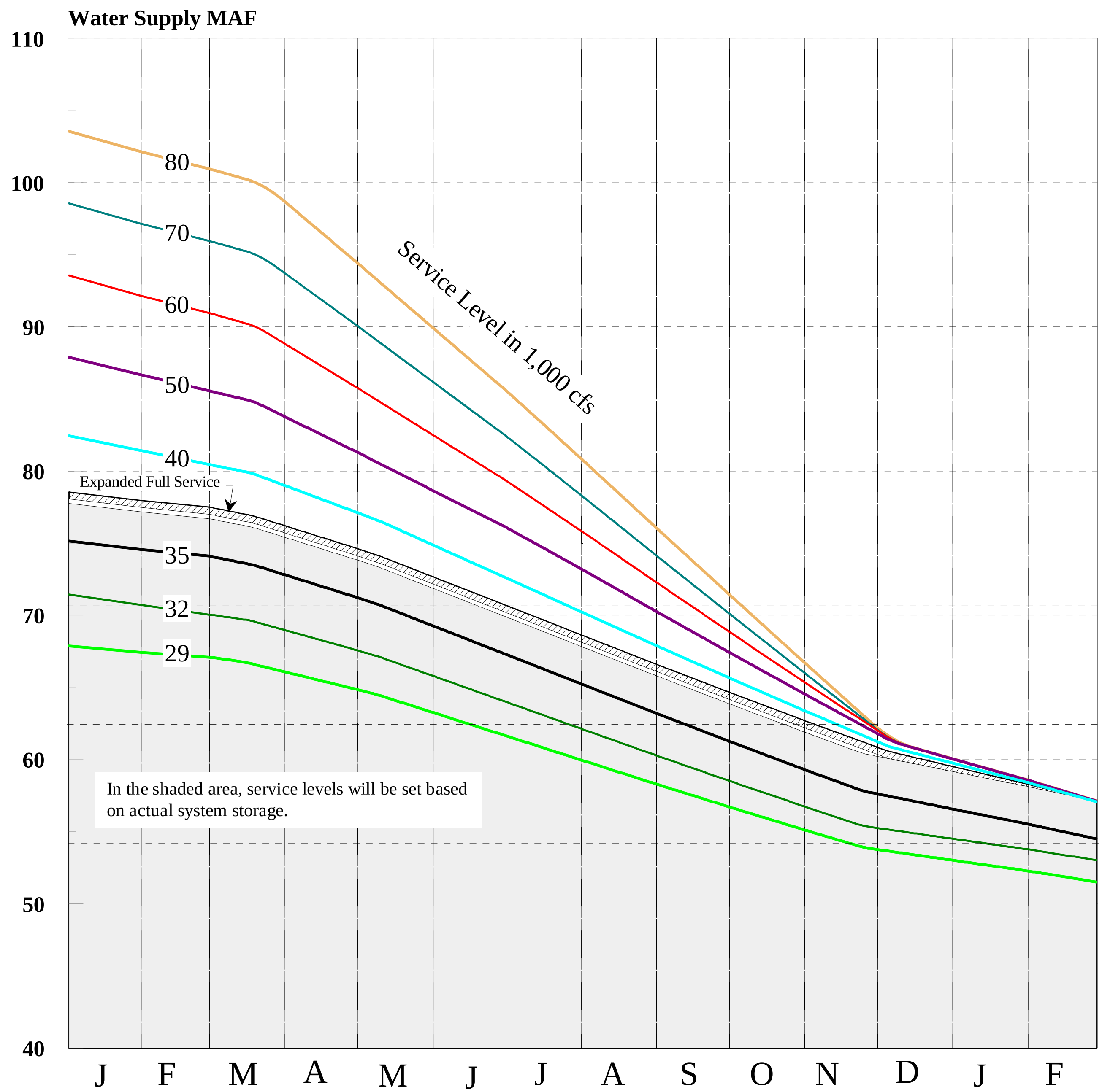
STORAGE DIFFERENCE IN THE REMARKS IS -243000.
STORAGE ACCUMULATION IN THE TOTALS IS -242975.



Missouri River Basin Physical Communications Diagram

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate V-5



Notes:

1. Water supply consists of the accumulation of the following:
   a. Actual system storage
   b. Forecast remaining calendar year runoff volume (1949 basin development level) above Gavins Point Dam.
   c. Departure of total tributary storage from base level. (See text.)

2. Expanded full service consists of the following:
   a. Maintenance of 35,000 cfs service level through the navigation season.
   b. Extension of the navigation season for up to 10 days beyond the normal closing date of 1 December at the mouth of the Missouri River.
   c. Winter releases averaging 20,000 cfs from Gavins Point.

3. The relationship between the service level and target flow is as given in the table below:

Target Flows - 1,000 cfs

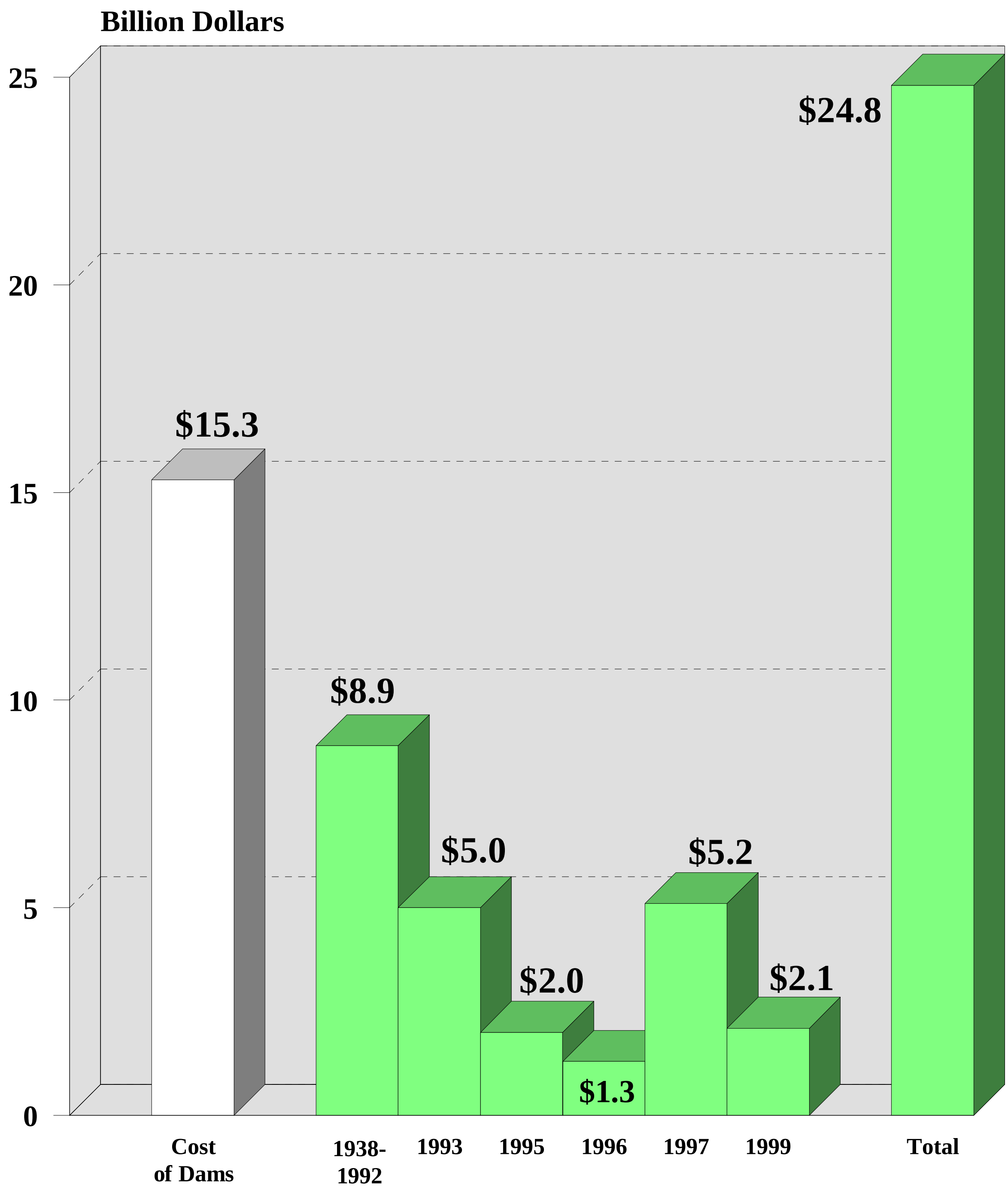
Service Level	Sioux City & Omaha	Nebraska City	Kansas City
29.0 1/	25.0	31.0	35.0
35.0 2/	31.0	37.0	41.0
40.0 3/	36.0	42.0	46.0
50.0 3/	46.0	52.0	56.0

1/ Minimum service level
2/ Full service level
3/ Storage evacuation service level

Missouri River Mainstem Reservoir System Service Level

U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
MARCH 2004

Missouri River Mainstem Reservoirs
Flood Damages Prevented Indexed to 2001



Missouri River Basin
Mainstem Flood Damages Prevented
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
NOVEMBER 2003
Plate VI-2

0600 HOUR TRIBUTARY FLOWS KCFS

	OBSERVED				TDY	FORECAST						
DATES	5	6	7	8	9	10	11	12	13	14	15	16
						17	18	19	20	21	22	23
GAPF	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
						26.0	26.0	26.0	26.0	26.0	26.0	26.0
SCSF	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
VRSF	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
NCSF	0.2	0.2	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
RVIF	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
ANIF	0.1	1.7	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
MPIF	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
LVIF	0.6	0.6	0.6	0.8	0.9	0.9	0.8	0.6	0.5	0.5	0.5	0.5
						0.5	0.5	0.5	0.5	0.5	0.5	0.5
TUMF	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
LGIF	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
PSIF	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
KENF	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0	0.0
MLNF	1.7	1.5	1.0	1.2	1.6	1.6	1.5	1.3	1.2	1.0	1.0	1.0
						1.0	1.0	1.0	1.0	1.0	1.0	1.0
NLNF	0.4	0.6	0.4	0.5	0.6	0.6	0.6	0.5	0.4	0.4	0.4	0.4
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
OFKF	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
						0.6	0.6	0.6	0.6	0.6	0.6	0.6
GWNF	0.1	0.3	0.2	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
ACIF	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
HCKF	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
AGYF	0.1	0.2	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
DESF	3.0	2.8	2.9	2.5	2.4	2.3	2.2	2.2	2.2	2.1	2.0	2.0
						1.9	1.9	1.8	1.8	1.8	1.8	1.8
CHMF	0.0	0.0	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
BAGF	3.2	3.2	3.2	3.2	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
						0.8	0.8	0.8	0.8	0.8	0.8	0.8

THIS FORECAST IS PREPARED BY THE CORPS OF ENGINEERS MISSOURI RIVER REGION FOR REGULATION OF RESERVOIR RELEASES AND IS FOR INTERNAL USE AND NOT FOR GENERAL DISTRIBUTION. THE NATIONAL WEATHER SERVICE PREPARES AND DISTRIBUTES RIVER STAGE FORECASTS TO THE GENERAL PUBLIC.

RESERVOIR CONTROL CENTER

FUI Tributary Flows

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

0600 HOUR UNGAGED FLOWS KCFS

	OBSERVED				TDY	FORECAST						
DATES	5	6	7	8	9	10	11	12	13	14	15	16
						17	18	19	20	21	22	23
AKIF	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
						0.5	0.5	0.5	0.5	0.5	0.5	0.5
SUXF	0.7	0.5	0.5	0.6	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
JMIF	0.2	0.1	-0.5	-1.0	-0.6	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
						-0.5	-0.5	-0.5	-0.5	-0.5	-0.5	-0.5
CEIF	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.4	0.3	0.3	0.3	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
TUIF	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
OMAF	0.5	0.0	0.1	0.9	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
GRNF	0.4	0.4	0.4	0.6	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
WSNF	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
WTNF	0.6	0.5	0.8	0.8	0.6	0.6	0.6	0.5	0.5	0.5	0.4	0.4
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
LUNF	1.2	0.8	0.4	1.2	1.3	1.0	0.9	0.8	0.6	0.5	0.4	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
NCNF	1.0	1.5	0.4	0.7	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
HAIF	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.5	0.4	0.4	0.4
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
RUNF	0.6	0.5	1.1	0.4	1.3	0.5	0.4	0.4	0.3	0.3	0.3	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
STJF	-0.1	0.3	0.1	-0.2	0.1	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
						-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4
SSMF	0.0	0.1	0.3	0.5	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
						0.1	0.1	0.1	0.1	0.1	0.1	0.1
MKCF	0.7	1.4	1.3	0.2	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
WVMF	0.9	1.2	1.9	1.7	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
						0.4	0.4	0.4	0.4	0.4	0.4	0.4
BNMF	5.8	7.5	4.1	4.4	4.4	4.0	3.5	3.0	2.5	2.0	2.0	2.0
						2.0	2.0	2.0	2.0	2.0	2.0	2.0
HEMF	2.1	2.8	1.7	1.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
						0.5	0.5	0.5	0.5	0.5	0.5	0.5

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RESERVOIR CONTROL CENTER

FUI Ungaged Flows

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

MISSOURI RIVER FORECAST

0600 HOUR STATION FLOWS KCFS

	OBSERVED				TDY	FORECAST						
DATES	5	6	7	8	9	10	11	12	13	14	15	16
						17	18	19	20	21	22	23
GAPF	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0	26.0
						26.0	26.0	26.0	26.0	26.0	26.0	
BAGF	3.2	3.2	3.2	3.2	9.0	9.0	9.0	9.0	9.0	0.8	0.8	1.5
						1.5	1.5	1.5	1.5	0.5	0.5	
AKIF	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.0	1.0	0.9	0.9	0.9
						0.8	0.8	0.8	0.8	0.8	0.8	0.8
SUXF	28.1	27.9	27.9	28.0	27.8	27.8	27.8	27.8	27.8	27.8	27.7	27.7
						27.6	27.6	27.6	27.5	27.5	27.5	27.5
TUIF	1.7	1.7	1.6	1.7	1.8	1.8	1.9	1.9	1.8	1.7	1.5	1.4
						1.4	1.3	1.3	1.3	1.3	1.3	1.3
OMAF	31.6	31.2	31.2	32.1	31.8	31.5	31.4	31.4	31.3	31.1	30.8	30.6
						30.4	30.3	30.1	30.1	30.0	30.0	30.0
GRNF	0.4	0.4	0.4	0.6	0.4	0.4	0.4	0.3	0.3	0.2	0.2	0.2
						0.2	0.2	0.2	0.2	0.2	0.2	0.2
WTNF	1.5	1.4	1.7	1.7	1.6	1.5	1.4	1.3	1.3	1.2	1.2	1.1
						1.1	1.1	1.1	1.1	1.1	1.1	1.1
LUNF	4.5	4.4	4.4	5.4	5.4	4.9	4.9	4.8	4.6	4.3	4.0	3.6
						3.5	3.4	3.3	3.3	3.2	3.2	3.2
NCNF	36.2	37.5	36.4	37.3	37.7	37.0	36.5	36.4	36.2	35.9	35.3	34.8
						34.3	33.9	33.7	33.6	33.5	33.4	33.4
HAIF	1.2	1.2	1.2	1.2	1.2	1.2	1.1	1.0	1.0	0.9	0.9	0.9
						0.9	0.9	0.9	0.9	0.9	0.9	0.9
RUNF	38.4	38.4	39.0	38.4	40.0	39.1	38.3	37.9	37.7	37.3	36.8	36.3
						35.7	35.3	35.0	34.9	34.7	34.7	34.6
STJF	38.5	38.7	38.9	38.3	38.5	39.4	38.3	37.7	37.4	37.1	36.7	36.2
						35.6	35.1	34.8	34.5	34.4	34.3	34.2
SSMF	0.2	0.2	0.5	0.8	0.5	0.3	0.3	0.3	0.3	0.3	0.3	0.3
						0.3	0.3	0.3	0.3	0.3	0.3	0.3
MKCF	42.6	43.0	43.2	42.5	41.8	42.7	41.8	40.7	40.3	40.0	39.5	39.0
						38.4	37.8	37.3	37.0	36.8	36.6	36.5
WVMF	43.7	43.6	45.2	44.7	42.8	42.4	42.9	41.9	41.0	40.6	40.3	39.8
						39.2	38.6	38.1	37.6	37.3	37.1	37.0
BNMF	51.4	51.4	47.9	49.6	48.9	46.9	46.1	45.8	44.3	43.1	42.7	42.3
						41.9	41.3	40.7	40.2	39.8	39.5	39.3
HEMF	52.2	55.1	53.6	52.1	52.8	52.6	55.3	55.7	55.3	54.1	51.8	47.5
						44.9	43.8	43.3	42.8	42.3	41.8	41.3

RESULTS OF RELEASE FOR DATE					SVC LEVEL EXCEEDED				FULL SVC FC Q		
DATE	SUXF	OMAF	NCNF	MKCF	SUXF	OMAF	NCNF	MKCF	MIN SVC FC Q		
									OMAF	NCNF	MKCF
9JUN	27.8	31.4	36.2	39.8	2.8	6.4	5.2	4.8	10.0	10.0	30.0
10JUN	27.8	31.3	35.9	39.3	2.8	6.3	4.9	4.3	15.0	20.0	60.0
11JUN	27.8	31.1	35.3	38.7	2.8	6.1	4.3	3.7			
12JUN	27.8	30.8	34.8	38.1	2.8	5.8	3.8	3.1			
13JUN	27.7	30.6	34.3	37.5	2.7	5.6	3.3	2.5			
14JUN	27.7	30.4	33.9	37.1	2.7	5.4	2.9	2.1			
15JUN	27.6	30.3	33.7	36.9	2.6	5.3	2.7	1.9			
16JUN	27.6	30.1	33.6	36.7	2.6	5.1	2.6	1.7			
17JUN	27.6	30.1	33.5	36.6	2.6	5.1	2.5	1.6			
18JUN	27.5	30.0	33.4	36.4	2.5	5.0	2.4	1.4			

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RESERVOIR CONTROL CENTER

FUI Combined Flows

0600 HOUR STAGES AND CHANGES

	OBSERVED				TDY	FORECASTED						
DATES	5	6	7	8	9	10	11	12	13	14	15	16
						17	18	19	20	21	22	23
AKIF	6.6	6.6	6.6	6.6	6.8	6.8	6.8	6.7	6.5	6.4	6.3	6.2
						6.1	6.1	6.0	6.0	6.0	6.0	6.0
*DIF	0.0	0.0	0.0	0.0	0.1	0.1	0.0	-0.1	-0.2	-0.1	-0.1	-0.1
						-0.1	0.0	0.0	0.0	0.0	0.0	0.0
SUXF	14.4	14.3	14.3	14.4	14.3	14.3	14.3	14.3	14.3	14.3	14.3	14.3
						14.3	14.2	14.2	14.2	14.2	14.2	14.2
*DIF	0.0	-0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0	0.0
OMAF	16.1	16.0	16.0	16.3	16.2	16.1	16.1	16.1	16.1	16.0	15.9	15.9
						15.8	15.8	15.8	15.7	15.7	15.7	15.7
*DIF	0.0	-0.1	0.0	0.2	-0.1	-0.1	0.0	0.0	0.0	-0.1	-0.1	-0.1
						-0.1	0.0	0.0	0.0	0.0	0.0	0.0
GRNF	3.4	3.4	3.5	3.5	3.4	3.4	3.4	3.4	3.3	3.2	3.2	3.2
						3.2	3.2	3.2	3.2	3.2	3.2	3.2
*DIF	0.0	0.0	0.0	0.1	-0.1	0.0	0.0	0.0	-0.1	-0.1	0.0	0.0
						0.0	0.0	0.0	0.0	0.0	0.0	0.0
WTNF	3.8	3.8	4.2	4.2	4.0	3.9	3.8	3.7	3.6	3.5	3.4	3.3
						3.3	3.3	3.3	3.3	3.3	3.3	3.3
*DIF	0.0	0.0	0.3	0.0	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1
						0.0	0.0	0.0	0.0	0.0	0.0	0.0
LUNF	3.6	3.6	3.6	3.8	3.8	3.7	3.7	3.7	3.6	3.5	3.4	3.3
						3.3	3.2	3.2	3.2	3.2	3.2	3.2
*DIF	0.0	0.0	0.0	0.3	0.0	-0.1	0.0	0.0	0.0	-0.1	-0.1	-0.1
						-0.1	0.0	0.0	0.0	0.0	0.0	0.0
NCNF	9.4	9.7	9.4	9.6	9.7	9.5	9.4	9.4	9.4	9.3	9.1	9.0
						8.9	8.8	8.7	8.7	8.7	8.6	8.6
*DIF	0.0	0.3	-0.3	0.2	0.1	-0.2	-0.1	0.0	0.0	-0.1	-0.1	-0.1
						-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
RUNF	9.2	9.2	9.4	9.2	9.4	9.4	9.2	9.1	9.0	8.9	8.8	8.7
						8.5	8.4	8.4	8.3	8.3	8.3	8.3
*DIF	0.0	0.0	0.1	-0.2	0.2	0.0	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1
						-0.1	-0.1	-0.1	0.0	0.0	0.0	0.0
STJF	8.7	8.8	8.8	8.7	8.7	9.0	8.7	8.5	8.5	8.4	8.3	8.1
						8.0	7.9	7.8	7.7	7.7	7.7	7.7
*DIF	0.0	0.1	0.1	-0.2	0.1	0.2	-0.3	-0.2	-0.1	-0.1	-0.1	-0.1
						-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
MKCF	10.8	10.9	10.9	10.8	10.7	10.8	10.7	10.4	10.3	10.3	10.2	10.1
						9.9	9.8	9.7	9.6	9.6	9.6	9.5
*DIF	0.0	0.1	0.0	-0.1	-0.1	0.2	-0.2	-0.2	-0.1	-0.1	-0.1	-0.1
						-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0
WVMF	11.4	11.3	11.6	11.5	11.2	11.1	11.2	11.1	10.9	10.8	10.8	10.7
						10.6	10.5	10.4	10.3	10.3	10.3	10.2
*DIF	0.0	0.0	0.2	-0.1	-0.3	-0.1	0.1	-0.2	-0.1	-0.1	-0.1	-0.1
						-0.1	-0.1	-0.1	-0.1	-0.1	0.0	0.0
BNMF	8.6	8.0	8.1	8.4	8.3	8.0	7.8	7.8	7.5	7.3	7.2	7.1
						7.1	7.0	6.8	6.7	6.7	6.6	6.6
*DIF	0.0	-0.6	0.1	0.3	-0.1	-0.3	-0.1	-0.1	-0.3	-0.2	-0.1	-0.1
						-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	0.0
HEMF	6.6	6.9	6.7	6.5	6.6	6.6	7.0	7.0	7.0	6.8	6.5	5.9
						5.5	5.4	5.3	5.2	5.1	5.1	5.0
*DIF	0.0	0.3	-0.2	-0.2	0.1	0.0	0.4	0.1	-0.1	-0.2	-0.3	-0.6
						-0.3	-0.2	-0.1	-0.1	-0.1	-0.1	-0.1

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RESERVOIR CONTROL CENTER

FUI Stages

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate VI - 6

Missouri River Basin
FINAL Calendar Year 1997 Runoff
Historic and Forecasted

21-Aug-98

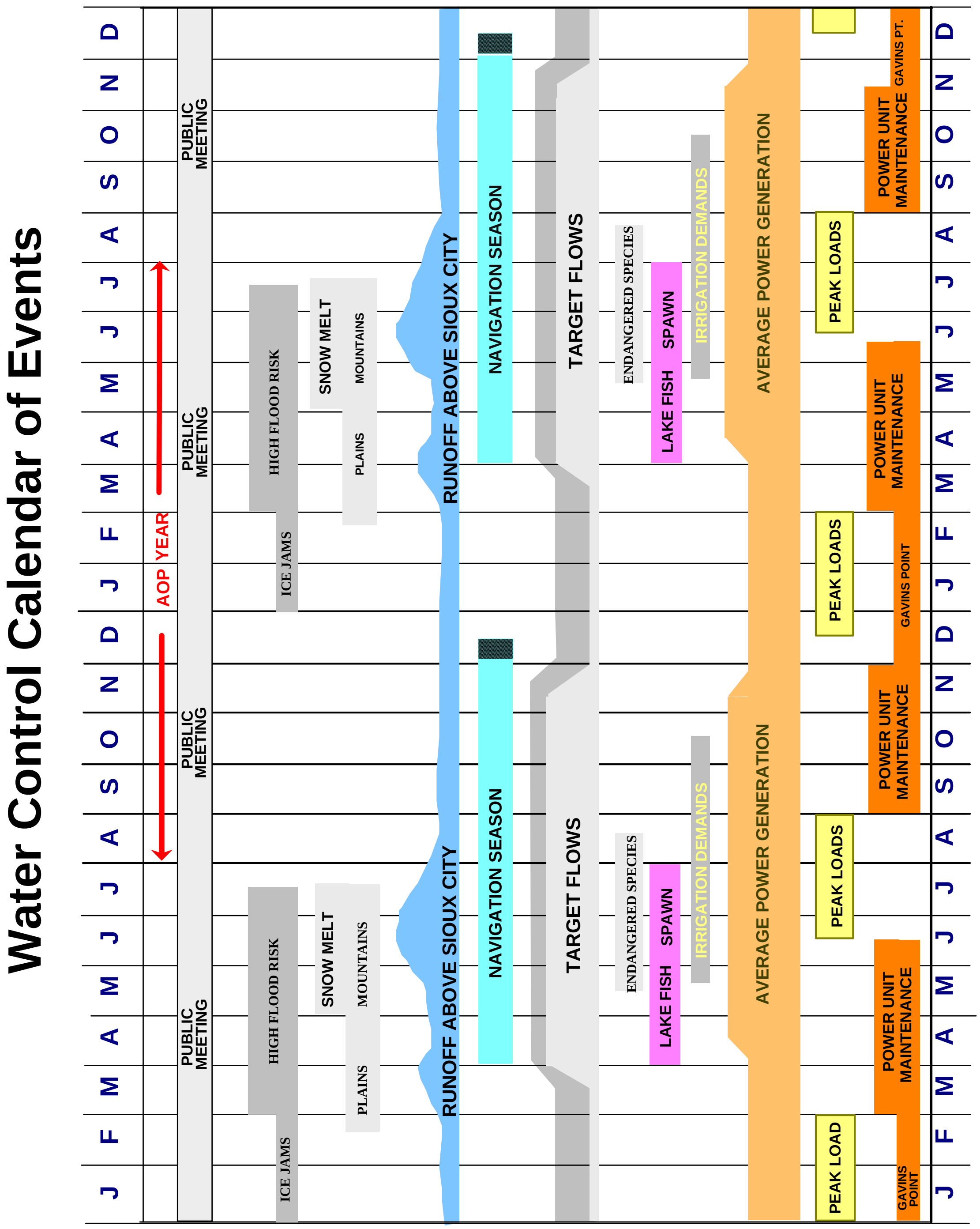
Values in 1000 Acre-Feet

Reach Above	Fort Peck	Garrison	Oahe	Fort Randall	Gavins Point	Sioux City	Summation above Gavins Point	Summation above Sioux City	Accumulated Summation above Sioux City
	(Historic)								
JAN 97	512	267	168	114	258	166	1,319	1,485	1,485
NORMAL	315	265	10	20	95	25	705	730	730
DEPARTURE	197	2	158	94	163	141	614	755	755
% OF NOR	163%	101%	1680%	570%	272%	664%	187%	203%	203%
FEB 97	582	646	516	589	436	134	2,769	2,903	4,388
NORMAL	360	350	70	40	120	80	940	1,020	1,750
DEPARTURE	222	296	446	549	316	54	1,829	1,883	2,638
% OF NORM	162%	185%	737%	1473%	363%	168%	295%	285%	251%
MAR 97	717	1,890	2,604	845	405	783	6,461	7,244	11,632
NORMAL	600	990	545	215	200	290	2,550	2,840	4,590
DEPARTURE	117	900	2,059	630	205	493	3,911	4,404	7,042
% OF NORM	120%	191%	478%	393%	203%	270%	253%	255%	253%
APR 97	631	1,974	2,828	451	356	2,376	6,240	8,616	20,248
NORMAL	670	1,120	480	140	170	300	2,580	2,880	7,470
DEPARTURE	-39	854	2,348	311	186	2,076	3,660	5,736	12,778
% OF NORM	94%	176%	589%	322%	209%	792%	242%	299%	271%
MAY 97	1,500	1,609	841	415	375	1,235	4,740	5,975	26,223
NORMAL	1,120	1,280	300	135	170	235	3,005	3,240	10,710
DEPARTURE	380	329	541	280	205	1,000	1,735	2,735	15,513
% OF NORM	134%	126%	280%	307%	221%	526%	158%	184%	245%
JUN 97	3,023	4,652	336	583	337	649	8,931	9,580	35,803
NORMAL	1,645	2,710	435	150	170	240	5,110	5,350	16,060
DEPARTURE	1,378	1,942	-99	433	167	409	3,821	4,230	19,743
% OF NORM	184%	172%	77%	389%	198%	270%	175%	179%	223%
JUL 97	1,231	2,917	263	105	274	360	4,790	5,150	40,953
NORMAL	820	1,790	165	60	125	180	2,960	3,140	19,200
DEPARTURE	411	1,127	98	45	149	180	1,830	2,010	21,753
% OF NORM	150%	163%	159%	175%	219%	200%	162%	164%	213%
AUG 97	586	1,271	4	154	287	324	2,302	2,626	43,579
NORMAL	350	615	60	45	110	110	1,180	1,290	20,490
DEPARTURE	236	656	-56	109	177	214	1,122	1,336	23,089
% OF NORM	167%	207%	7%	342%	261%	295%	195%	204%	213%
SEP 97	472	608	-8	17	244	165	1,333	1,498	45,077
NORMAL	340	480	115	45	105	85	1,085	1,170	21,660
DEPARTURE	132	128	-123	-28	139	80	248	328	23,417
% OF NORM	139%	127%	-7%	38%	232%	194%	123%	128%	208%
OCT 97	458	525	-140	16	193	184	1,052	1,236	46,313
NORMAL	395	525	70	10	115	65	1,115	1,180	22,840
DEPARTURE	63	0	-210	6	78	119	-63	56	23,473
% OF NORM	116%	100%	-200%	160%	168%	283%	94%	105%	203%
NOV 97	491	551	-39	-48	178	155	1,133	1,288	47,601
NORMAL	390	410	65	10	115	60	990	1,050	23,890
DEPARTURE	101	141	-104	-58	63	95	143	238	23,711
% OF NORM	126%	134%	-60%	-480%	155%	258%	114%	123%	199%
DEC 97	394	491	14	191	230	116	1,320	1,436	49,037
NORMAL	330	250	-5	5	90	40	670	710	24,600
DEPARTURE	64	241	19	186	140	76	650	726	24,437
% OF NORM	119%	196%	280%	3820%	256%	290%	197%	202%	199%
				Calendar Year Totals					
	10,597	17,401	7,387	3,432	3,573	6,647	42,390	49,037	
NORMAL	7,335	10,785	2,310	875	1,585	1,710	22,890	24,600	
DEPARTURE	3,262	6,616	5,077	2,557	1,988	4,937	19,500	24,437	
% OF NORM	144%	161%	320%	392%	225%	389%	185%	199%	

Missouri River Basin
Calendar Year Forecast

U.S. ARMY ENGINEER DIVISION, NORTHWESTEN
CORPS OF ENGINEERS, OMAHA, NEBRASKA

Plate VI-7

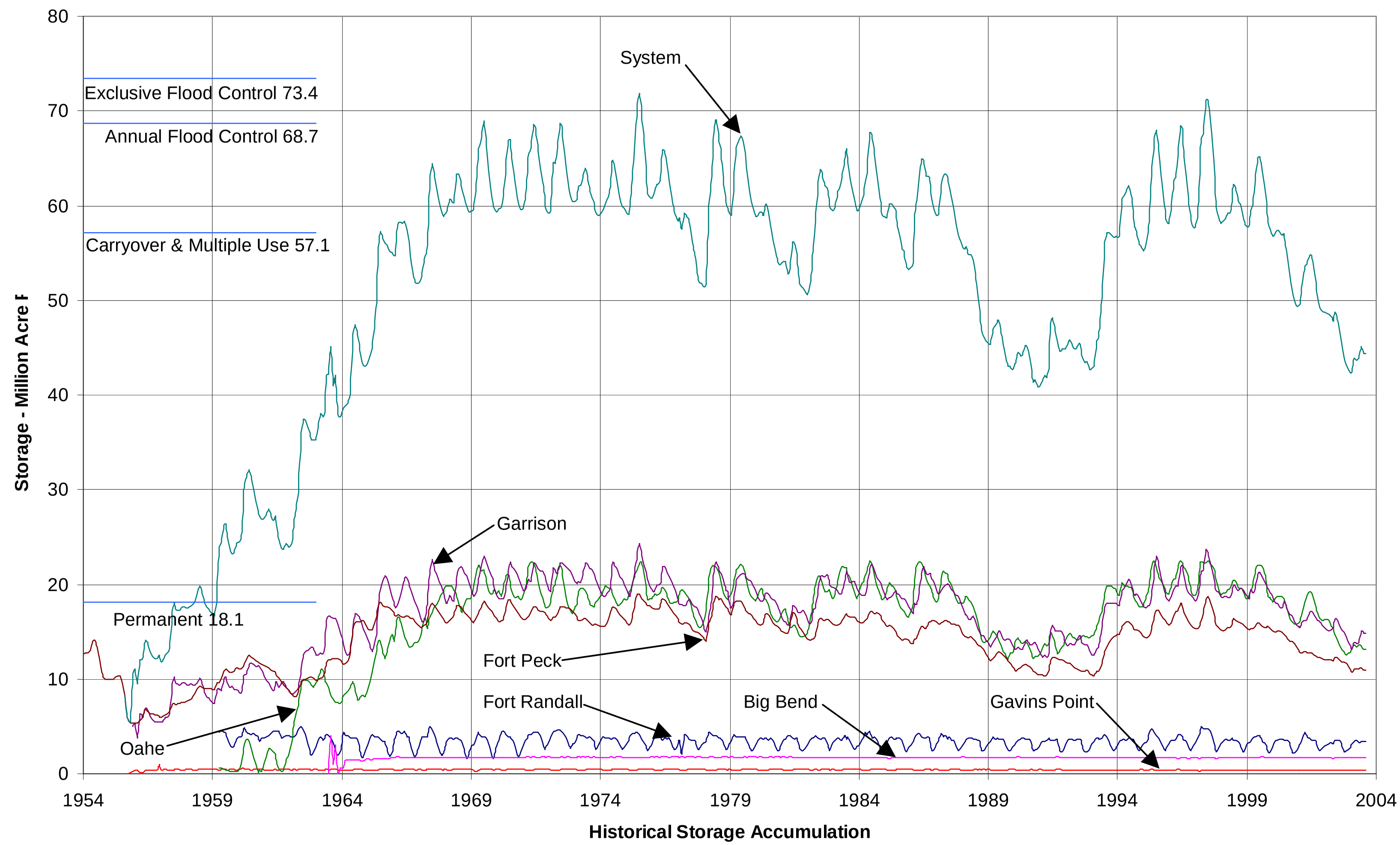


Missouri River Basin
Water Control
Calendar of Events

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate VII-1

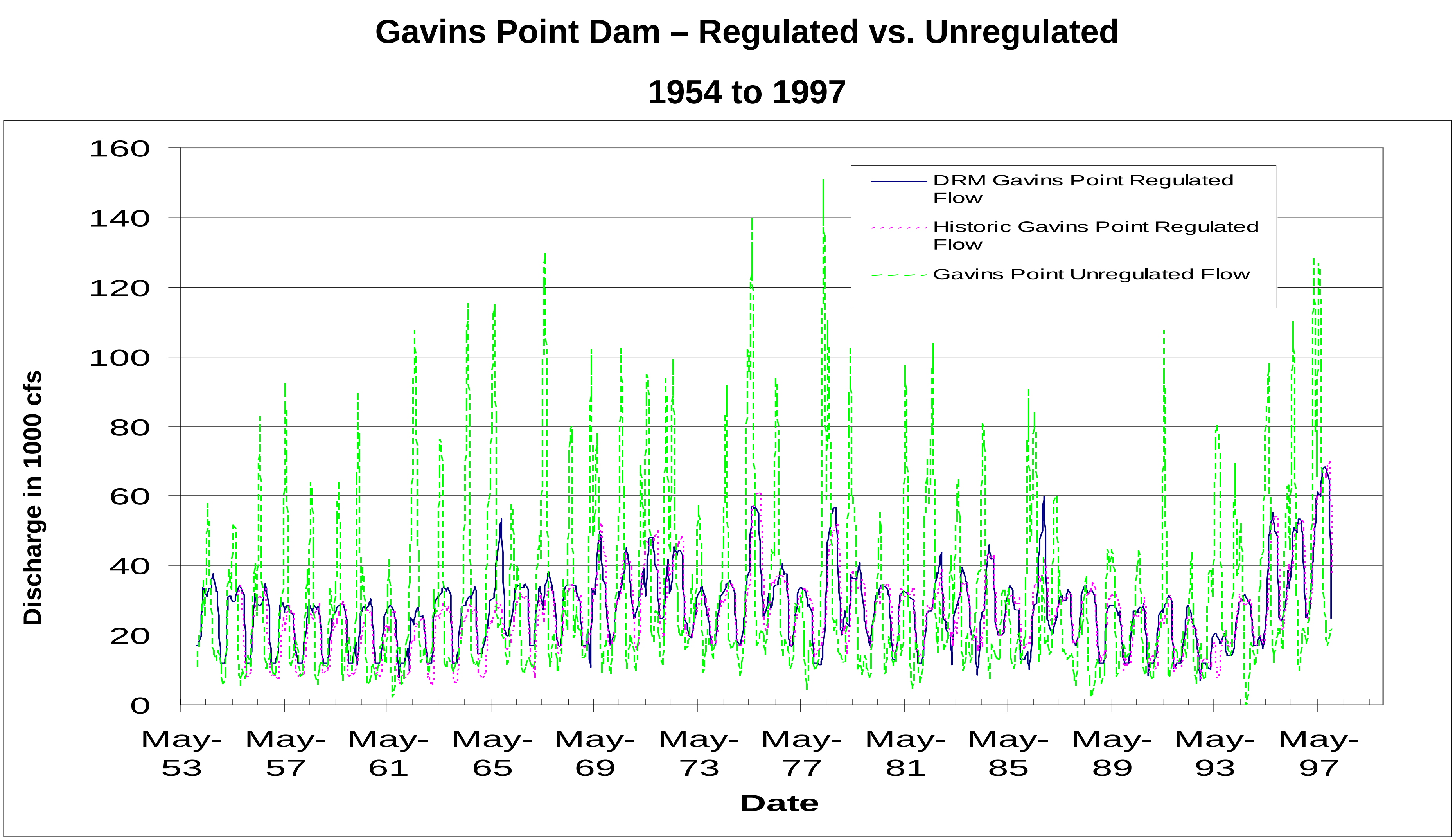
Historical Storage Accumulation for the System and 6 Mainstem Projects



Missouri River Basin
Historical Storage
Accumulation for the System
and 6 Mainstems

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
November 2003

Plate VII-2

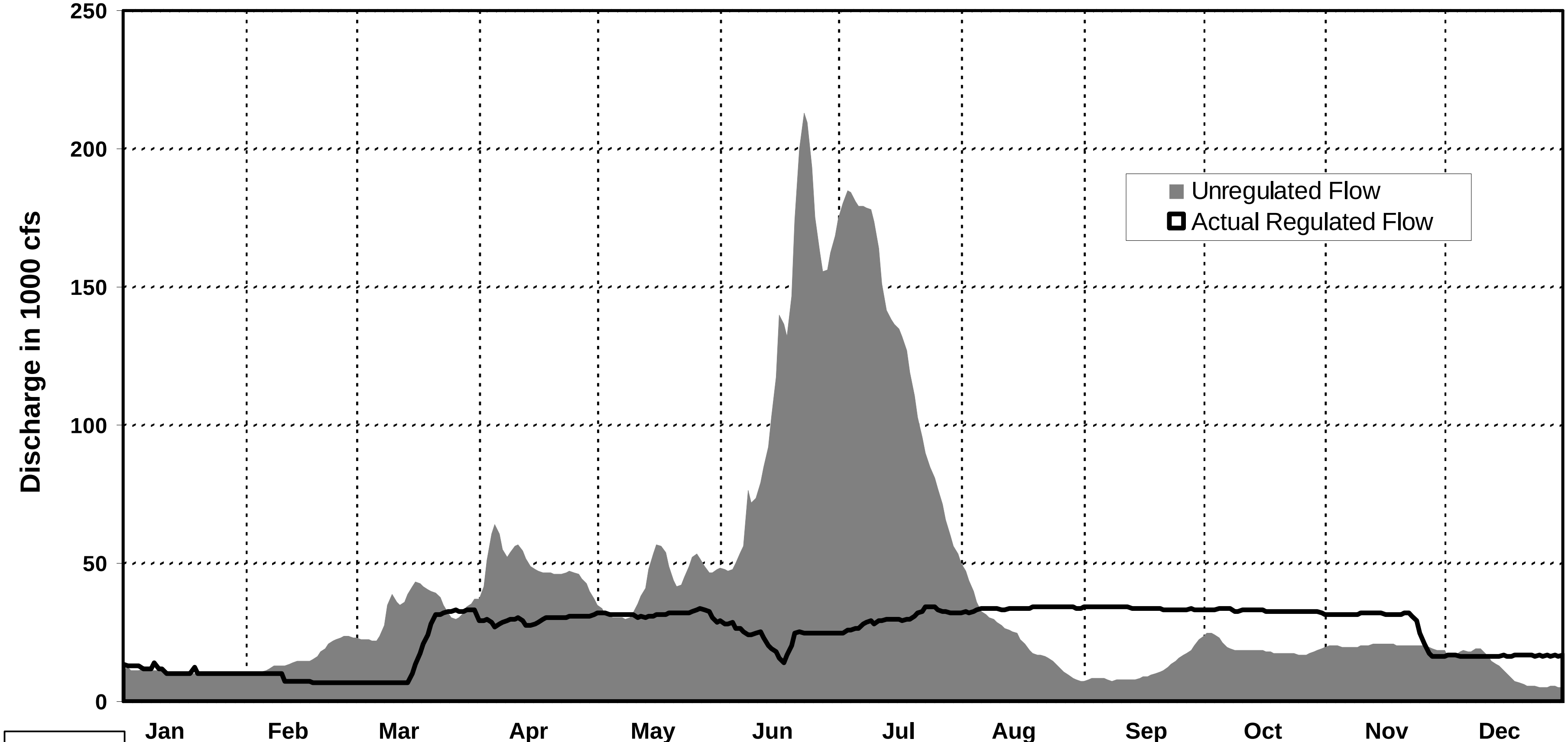


Missouri River Basin
Gavins Point Dam 1954-97
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Gavins Point Dam – Regulated vs. Unregulated

1967 Regulation



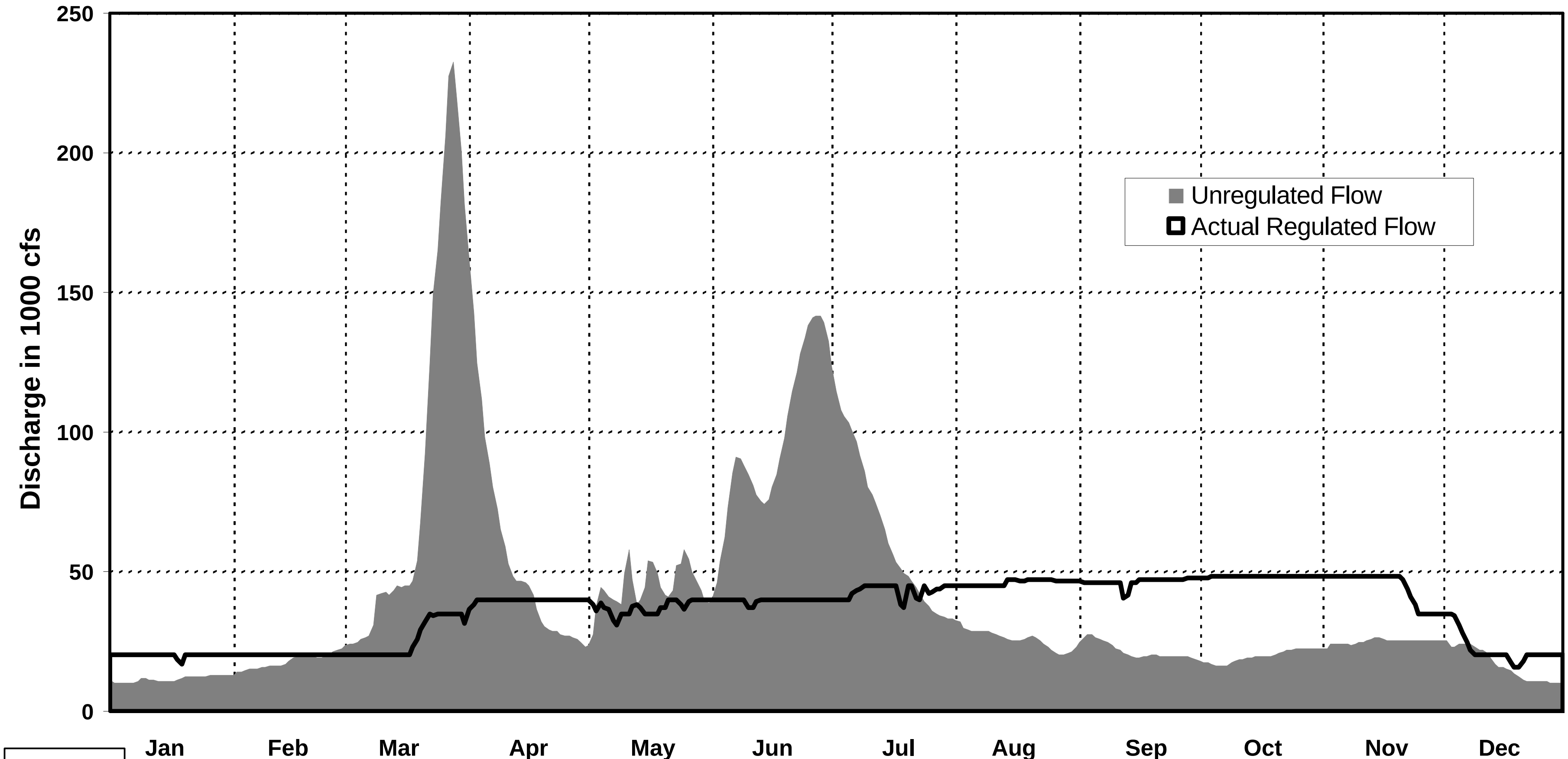
Missouri River Basin
Gavins Point Dam 1967
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate VII-4

Gavins Point Dam – Regulated vs. Unregulated

1972 Regulation

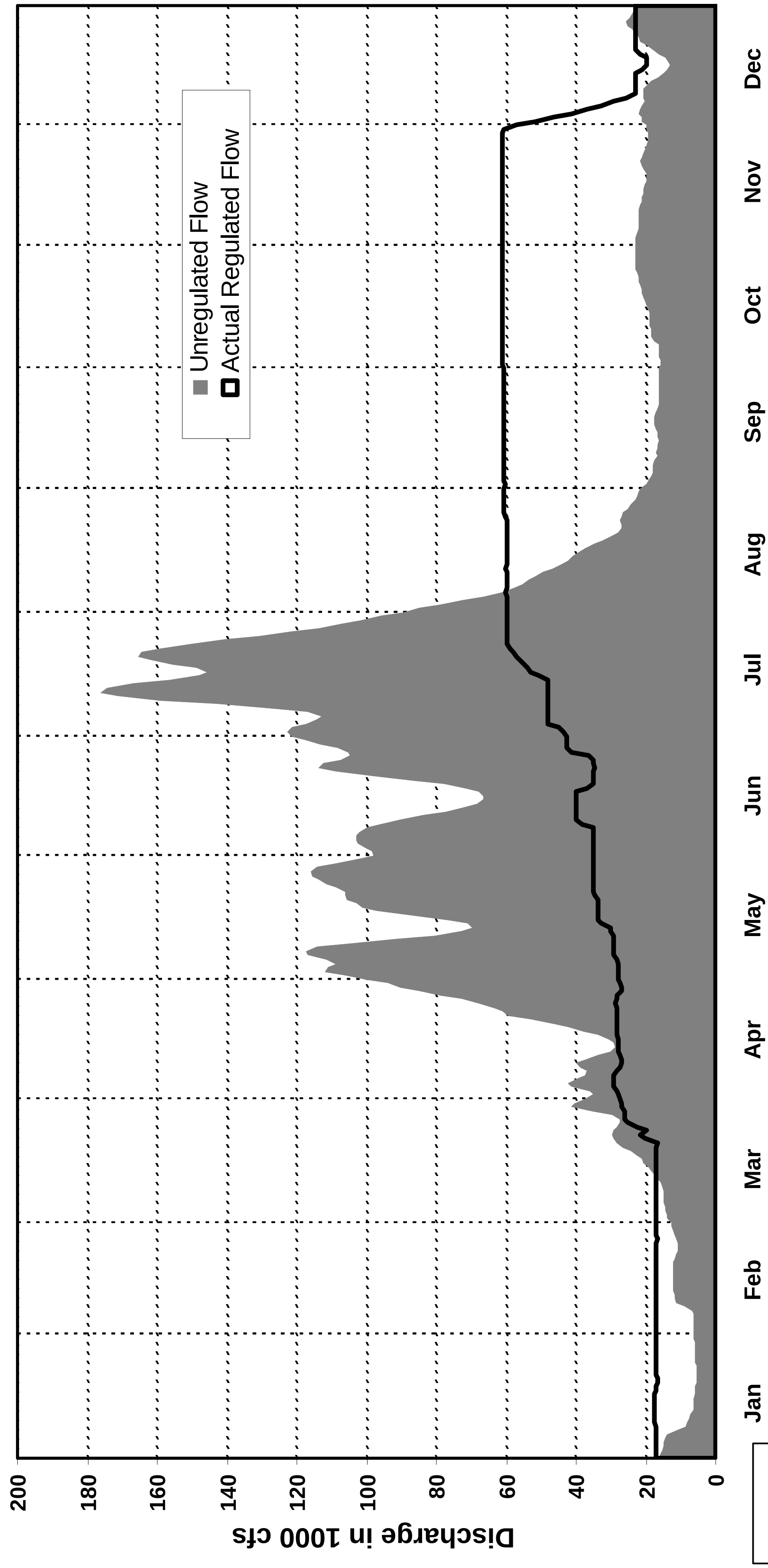


Missouri River Basin
Gavins Point Dam 1972
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Gavins Point Dam – Regulated vs. Unregulated

1975 Regulation



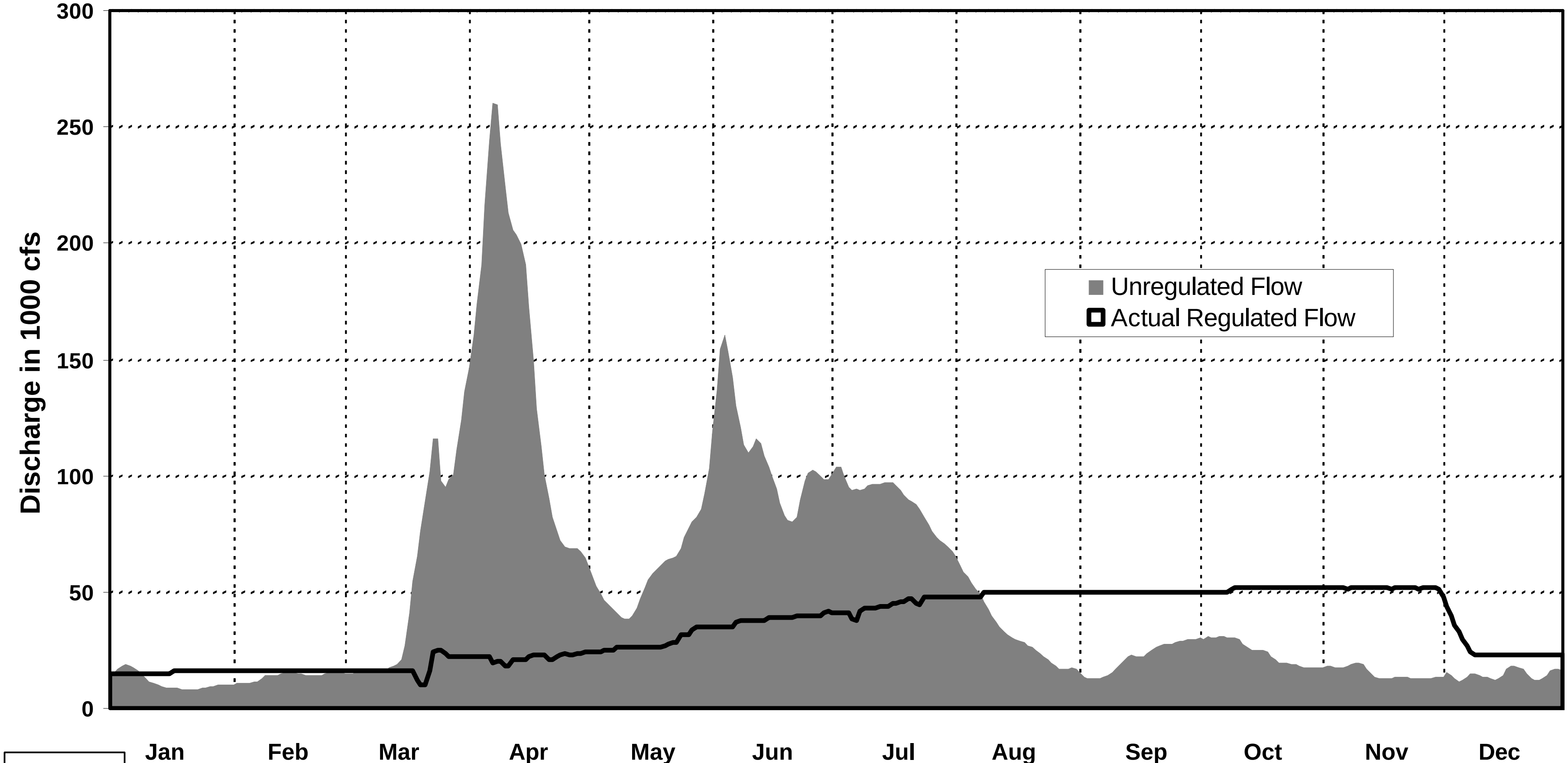
Missouri River Basin
Gavins Point Dam 1975
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate VII-6

Gavins Point Dam – Regulated vs. Unregulated

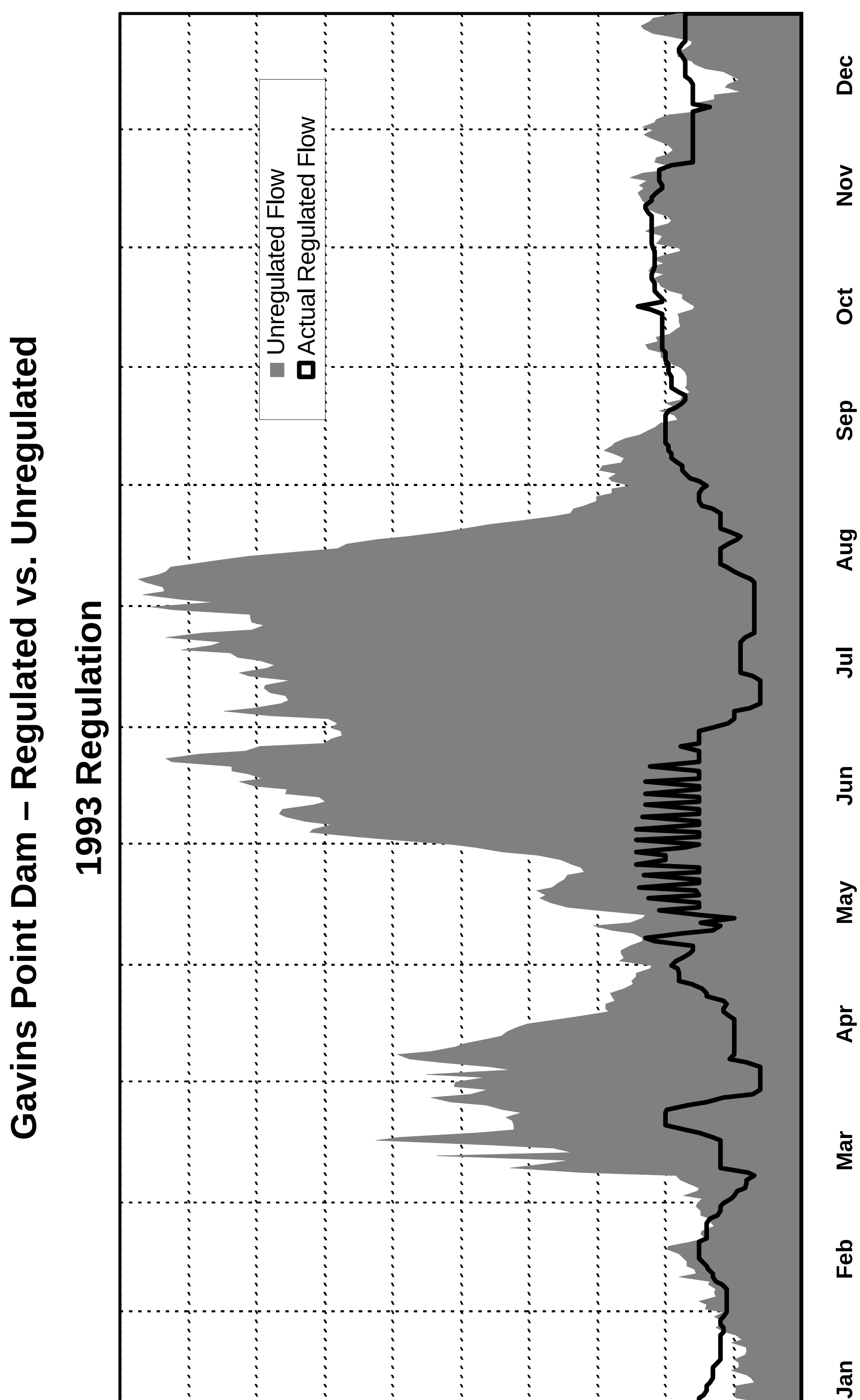
1978 Regulation



Missouri River Basin
Gavins Point Dam 1978
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

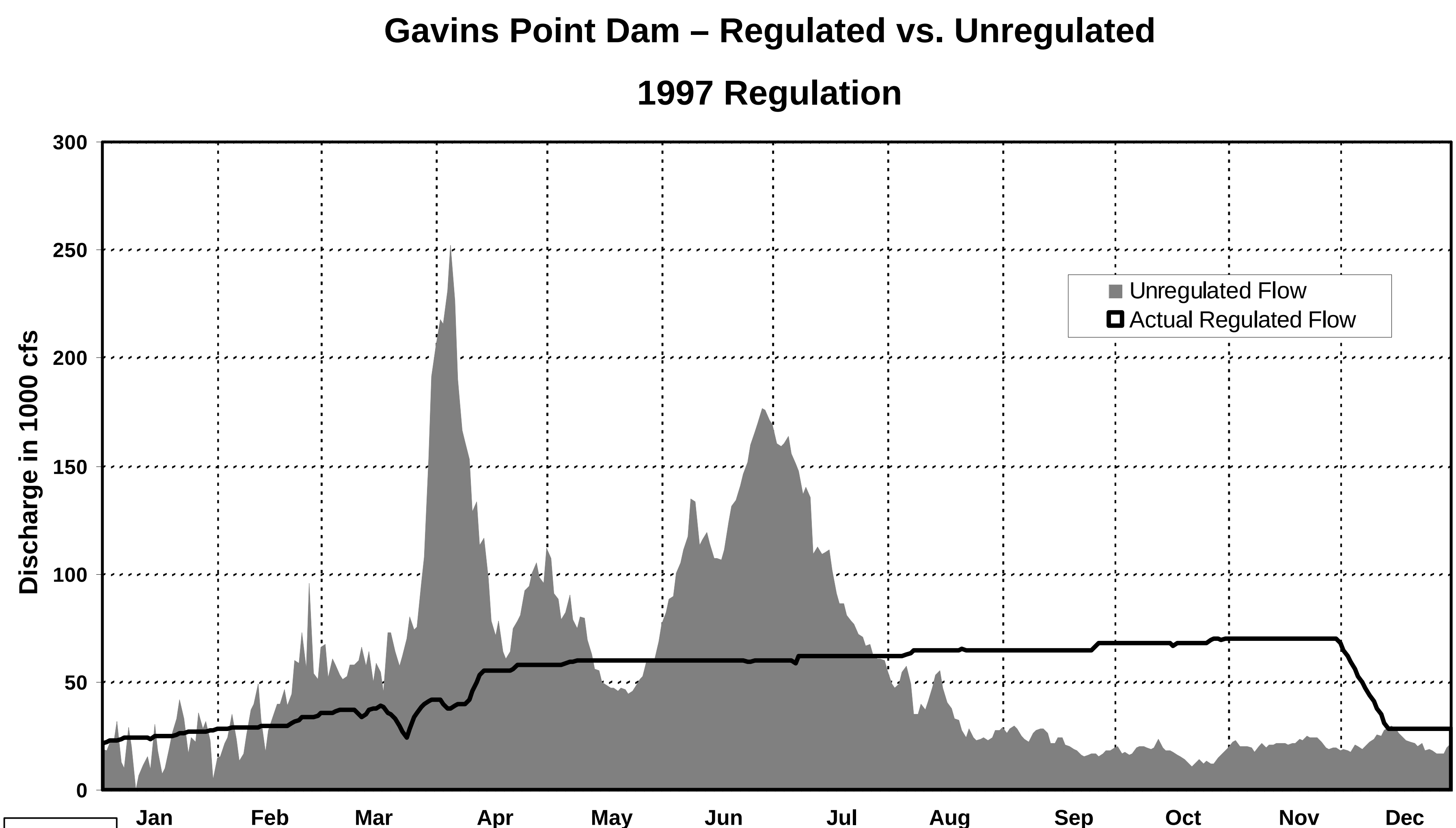
Plate VII-7



Missouri River Basin
Gavins Point Dam 1993
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate VII-8

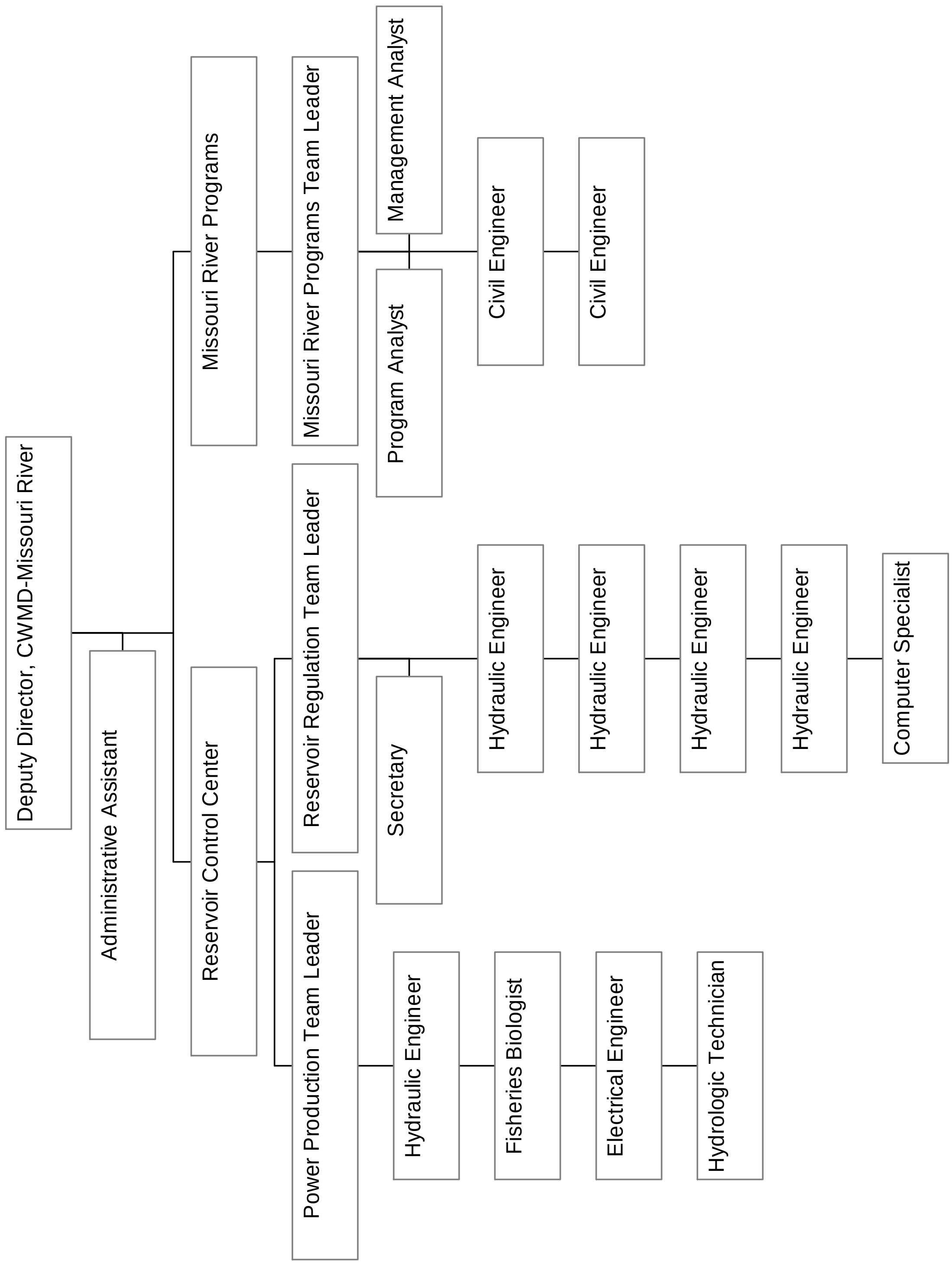


Missouri River Basin
Gavins Point Dam 1997
Regulation- Regulated vs.
Unregulated

U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Plate VII-9

NWD-Omaha
Missouri River Basin Division



Missouri River Basin
Organization Chart
U.S.ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
March 2004

Simulated Regulation For 1951-1952-1944-1945 Flood Combination - Sheet 1

							1951								1952	
		22-Mar	31-Mar	30-Apr	31-May	30-Jun	31-Jul	31-Aug	30-Sep	31-Oct	15-Nov	30-Nov	31-Dec	31-Jan	28-Feb	15-Mar
Fort Peck																
Reach Inflow, 1000 AF	8773	223	287	911	1499	1508	881	434	489	522	233	233	318	384	526	323
Evap, 1000 AF	481	0	0	0	33	24	93	96	90	62	28	28	24	0	0	0
Inflow Adjust, 1000 AF	-824	13	16	3	-465	-470	-294	43	133	-71	24	24	-34	162	88	2
Modified Inflow, 1000 AF	7467	236	304	914	1000	1013	493	380	531	388	228	226	259	546	614	325
Storage, 1000 AF	15300	15453	15669	16285	16610	16969	16725	16367	16453	16534	16614	16694	16259	16036	15950	15904
Pool Elev, FT-MSL	2234.4	2235.1	2236.1	2238.8	2240.2	2241.5	2240.7	2239.2	2239.6	2239.9	2240.3	2240.6	2238.7	2237.7	2237.4	2237.2
Release, 1000 AF	6863	83	89	297	676	654	737	737	446	307	148	148	694	768	700	371
Release, 1000 CFS	9.5	6.0	5.0	5.0	11.0	11.0	12.0	12.0	7.5	5.0	5.0	5.0	11.3	12.5	12.5	12.5
Ave Power, MW	132	82	69	69	153	154	168	167	105	70	70	70	157	173	173	173
Peak Power, MW		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Energy, 1000 MWH	1160.1	13.9	15.0	50.4	114.3	111.0	125.1	124.8	75.6	52.4	25.4	25.4	117.5	129.3	117.6	62.4
Garrison																
Reach Inflow, 1000 AF	11939	187	240	1969	1374	2201	1702	1044	822	717	321	321	90	319	484	147
Evap, 1000 AF	549	0	0	0	36	26	105	112	105	70	32	32	27	0	0	0
Inflow Adjust, 1000 AF	-606	33	43	55	-161	-492	-120	-165	-65	84	20	20	21	25	29	65
Modified Inflow, 1000 AF	17646	303	372	2321	1852	2337	2214	1504	1097	1038	456	456	778	1112	1213	585
Storage, 1000 AF	18200	18334	18261	19005	19411	20498	20868	20528	19841	20264	20423	20583	19977	19399	18931	18624
Pool Elev, FT-MSL	1837.0	1837.5	1837.2	1839.8	1840.8	1844.0	1845.0	1844.1	1842.2	1843.4	1843.8	1844.2	1842.5	1840.8	1839.3	1838.4
Release, 1000 AF	17221	168	446	1487	1537	1249	1844	1844	1785	614	297	297	1383	1690	1681	892
Release, 1000 CFS	23.8	12.2	25.0	25.0	25.0	21.0	30.0	30.0	30.0	10.0	10.0	10.0	22.5	27.5	30.0	30.0
Ave Power, MW	294	150	300	302	306	261	374	374	371	129	130	130	281	338	364	362
Peak Power, MW		446	445	455	459	460	460	460	460	460	460	460	460	459	453	449
Energy, 1000 MWH	2577.8	25.3	64.8	217.8	227.7	188.5	278.5	278.6	267.5	96.4	46.9	47.0	209.3	251.8	247.4	130.3
Oahe																
Reach Inflow, 1000 AF	1266	53	68	933	-78	185	50	20	105	44	-54	-54	-68	-71	78	53
Evap, 1000 AF	481	0	0	0	32	23	89	96	94	66	28	27	22	0	0	0
Inflow Adjust, 1000 AF	88	-14	-16	-39	80	-62	-37	-24	-37	-13	61	61	82	85	-22	-14
Modified Inflow, 1000 AF	18095	208	490	2381	1506	1349	1768	1744	1758	579	275	276	1375	1704	1737	932
Storage, 1000 AF	19100	18982	19122	20135	20412	20571	21110	21821	22495	21077	20249	9397	18659	18867	19610	20131
Pool Elev, FT-MSL	1607.1	1606.7	1607.1	1610.2	1611.1	1611.6	1613.2	1615.4	1617.2	1613.1	1610.6	1608.0	1605.7	1606.4	1608.6	1610.2
Release, 1000 AF	17063	325	357	1368	1229	1190	1229	1033	1084	1998	1103	1128	2112	1497	994	411
Release, 1000 CFS	23.6	23.4	20.0	23.0	20.0	20.0	20.0	16.8	18.2	32.5	37.1	37.9	34.4	24.4	17.7	13.8
Ave Power, MW	311	302	258	300	265	266	267	227	249	438	492	495	441	312	231	183
Peak Power, MW		685	685	685	685	685	685	685	685	685	685	685	685	685	685	685
Energy, 1000 MWH	2726.8	50.9	55.9	216.6	197.5	191.8	199.4	169.6	179.3	326.6	177.2	278.3	328.7	232.4	156.7	66.0
Big Bend																
Evap, 1000 AF	60	0	0	0	4	3	11	12	11	7	3	3	3	0	0	0
Ave Power, MW	107	106	89	100	85	84	82	69	79	155	181	185	168	116	81	61
Peak Power, MW		487	487	454	459	440	426	454	491	529	537	538	531	506	495	495
Energy, 1000 MWH	941.5	17.9	19.4	72.6	63.5	60.8	61.3	51.8	57.2	115.6	65.3	66.9	125.1	86.8	55.0	22.3
Fort Randall																
Reach Inflow 1000 AF	1181	33	42	103	131	218	77	23	56	100	60	60	6	24	119	128
Evap, 1000 AF	70	0	0	0	5	3	14	15	13	8	3	3	2	0	0	0
Inflow Adjust, 1000 AF	-161	-3	-4	-21	-19	-34	-33	-17	-17	-4	0	0	-1	-1	-1	-3
Modified Inflow, 1000 AF	17953	354	394	1450	1332	1367	1248	1011	1098	2077	1155	1180	2112	1520	1112	535
Storage, 1000 AF	3700	3783	3780	4116	4072	4262	4392	4115	3746	3218	2868	2543	3184	3598	3701	3701
Pool Elev, FT-MSL	1353.0	1354.0	1354.0	1357.9	1357.4	1359.5	1360.9	1357.9	1353.6	1346.9	1342.2	1337.5	1346.5	1351.8	1353.0	1353.0
Release, 1000 AF	17951	271	397	1115	1376	1177	1118	1288	1467	2606	1505	1505	1471	1106	1008	535
Release, 1000 CFS	24.8	19.6	22.3	18.7	22.4	19.8	18.2	21.0	24.7	42.4	50.6	50.6	23.9	18.0	18.0	18.0
Ave Power, MW	192	161	183	157	190	170	159	181	204	322	299	277	176	143	147	148
Peak Power, MW		338	338	353	352	360	365	353	337	307	285	264	305	329	334	334
Energy, 1000 MWH	1684.7	27.1	39.6	113.7	141.4	122.5	118.4	134.7	147.5	240.0	107.7	100.0	131.3	107.1	100.3	53.5
Gavins Point																
Reach Inflow, 1000 AF	2363	65	84	296	235	343	19.0	289	242	171	13	13	63	115	171	242
Evap, 1000 AF	31	0	0	0	2	1	6	6	6	4	1	1	1	0	0	0
Inflow Adjust, 1000 AF	-140	-4	-5	-5	-10	-24	-26	-38	-23	-14	6	6	1	1	0	-4
Release, 1000 AF	20143	332	476	1406	1599	1494	1104	1532	1679	2758	1523	1523	1533	1222	1179	773
Release, 1000 CFS	27.8	24.0	26.7	23.6	26.0	25.1	18.0	24.9	28.2	44.9	51.2	51.2	24.9	19.9	21.1	26.0
Ave Power, MW	75	72	79	71	77	75	56	75	83	95	92	92	75	61	64	77
Peak Power, MW		97	99	96	99	99	75	99	99	95	92	92	99	82	86	99
Energy, 1000 MWH	662.3	12.2	17.2	51.5	57.9	54.4	41.8	55.8	60.3	70.7	33.4	33.4	55.9	45.9	43.9	28.0
Mainstem System																
Reach Inflow, 1000 AF	29276	656	843	4989	3568	5089	3322	2092	2032	1721	562	562	431	725	1619	1044
Evap, 1000 AF	1675	0	0	0	113	82	319	339	321	219	99	98	81	0	0	0
Inflow Adjust, 1000 AF	-1872	21	27	-40	-595	-1114	-556	-240	-40	-27	110	110	68	271	90	41
Storage, 1000 AF	58300	58721	59001	61800	62673	64469	65264	65000	64703	63261	62323	61385	60248	60068	60360	60529
Ave Power, MW	1112	876	980	1003	1078	1012	1108	1095	1093	1211	1266	1252	1300	1146	1063	1006
Peak Power, MW		2255	2256	2246	2255	2244	2213	2252	2272	2277	2260	2240	2280	2263	2256	2264
Energy, 1000 MWH	9753.3	147.2	211.9	722.7	802.3	729.0	824.5	815.3	787.5	901.7	455.8	451.0	967.7	853.3	720.9	362.5
Service Level, 1000 CFS		35.0	35.0	35.0	35.0	35.0	38.0	41.0	45.0	55.0	60.0	60.0				
Navigation Season Length		20	20	20	20	20.0	20	20	20	20	20	20	20	20	20	20
Control Point		11	992	992	9992	9992	9992	9992	9992	994	994	994	11	11	11	11
Sioux City																
Reach Inflow, 1000 AF	3751	93	119	777	427	634	593	282	318	167	-12	-12	22	-46	241	147
Inflow Adjust, 1000 AF	-229	-3	-4	-33	-20	-32	-46	-39	-31	-9	0	0	-1	-1	-4	-3
Modified Inflow, 1000 AF	3522	89	115	744	407	602	547	243	287	158	-12	-12	21	-47	237	143
Flow, 1000 AF	23666	422	591	2149	2005	2096	1651	1775	1966	2916	1511	1511	1554	1175	1416	917
Flow, 1000 CFS	32.7	30.4	33.1	36.1	32.6	35.2	26.9	28.9	33.1	47.4	50.8	50.8	25.3	19.1	25.3	30.8
Omaha																
Reach Inflow, 1000 AF	3879	132	170	755	545	392	444	552	284	28	30	30	79	90	291	54
Inflow Adjust, 1000 AF	-33	-1	-2	-6	-6	-8	-6	-2	0	0	0	0	0	0	0	-1
Modified Inflow, 1000 AF	3846	131	168	749	539	384	438	550	284	28	30	30	79	90	291	53
Flow, 1000 AF	27485	528	751	2889	2555	2473	2115	2319	2238	2901	1531	1541	1710	1284	1689	954
Flow, 1000 CFS	37.9	38.0	42.1	48.6	41.6	41.6	34.4	37.7	37.6	47.2	51.5	51.8	27.8	20.9	30.1	32.1
Nebraska City																
Reach Inflow, 1000 AF	8035	275	354	573	912	1331	781	562	537	496	227	227	345	406	732	276
Inflow Adjust, 1000 AF	-947	-2	-3	7	-21	-87	-129	-129	-119	-84	-31	-31	3	-60	-182	-79
Modified Inflow, 1000 AF	7087	273	351	580	891	1244	652	433	418	412	196	196	348	346	550	197
Flow, 1000 AF	34564	792	1100	3466	3450	3714	2775	2750	2652	3299	1724	1737	2083	1636	2232	1145
Flow, 1000 CFS	47.7	57.1	61.6	58.3	56.1	62.4	45.1	44.7	44.6	53.7	58.0	58.4	33.9	26.6	39.9	38.5
Kansas City																
Reach Inflow, 1000 AF	28938	125	160	755	3153	5906	9363	2207	3460	1110	472	472	355	381	518	500
Inflow Adjust, 1000 AF	-333	0	-1	-50	-34	-1019	-808	802	-5	884	77	77	-6	-9	-30	-10
Modified Inflow, 1000 AF	28605	124	159	705	3119	4887	8555	3009	3455	1794	549	549	349	372	488	489
Flow, 1000 AF	63134	883	1249	4159	6583	8591	11363	5751	6090	5035	2260	2286	2534	2033	2696	1613
Flow, 1000 CFS	87.1	63.6	70.0	69.9	107.1	144.4	184.8	93.5	102.4	81.9	76.0	76.9	41.2	33.1	48.1	54.2
Boonville																
Reach Inflow, 1000 AF	13785	149	192	1490	845	1035	4722	939	1215	851	355	355	562	499	452	623
Inflow Adjust, 1000 AF	-93	-5	-7	-19	-19	-28	0	0	0	0	0	0	0	0	-9	-5
Modified Inflow, 1000 AF	13692	144	185	1471	826	1007	4722	939	1215	351	355	355	562	499	443	617
Flow, 1000 AF	76791	993	1423	5618	7423	9587	16119	6682	7288	5329	2601	2641	3199	2556	3114	2209
Flow, 1000 CFS	106.0	71.6	79.8	94.4	120.7	161.1	262.2	108.7	122.5	86.7	87.4	88.8	52.0	41.6	55.6	74.3
Hermann																
Reach Inflow, 1000 AF	28844	643	826	1778	1310	1440	8947	974	3993	1547	1262	1262	1326	1121	1703	710
Inflow Adjust, 1000 AF	-89	-22	-29	-86	-88	47	74	89	150	-82	-22	-22	-20	-19	-33	-24
Modified Inflow, 1000 AF	28754	620	797	1692	1222	1487	9021	1063	4143	1465	1240	1240	1306	1102	1670	685
Flow, 1000 AF	105528	1597	2216	7304	8652	11069	25157	7741	11423	6765	3834	3881	4556	3671	4772	2883
Flow, 1000 CFS	145.7	115.1	124.1	122.8	140.7	186.0	409.1	125.9	192.0	110.0	128.9	130.5	74.1	59.7	85.2	96.9

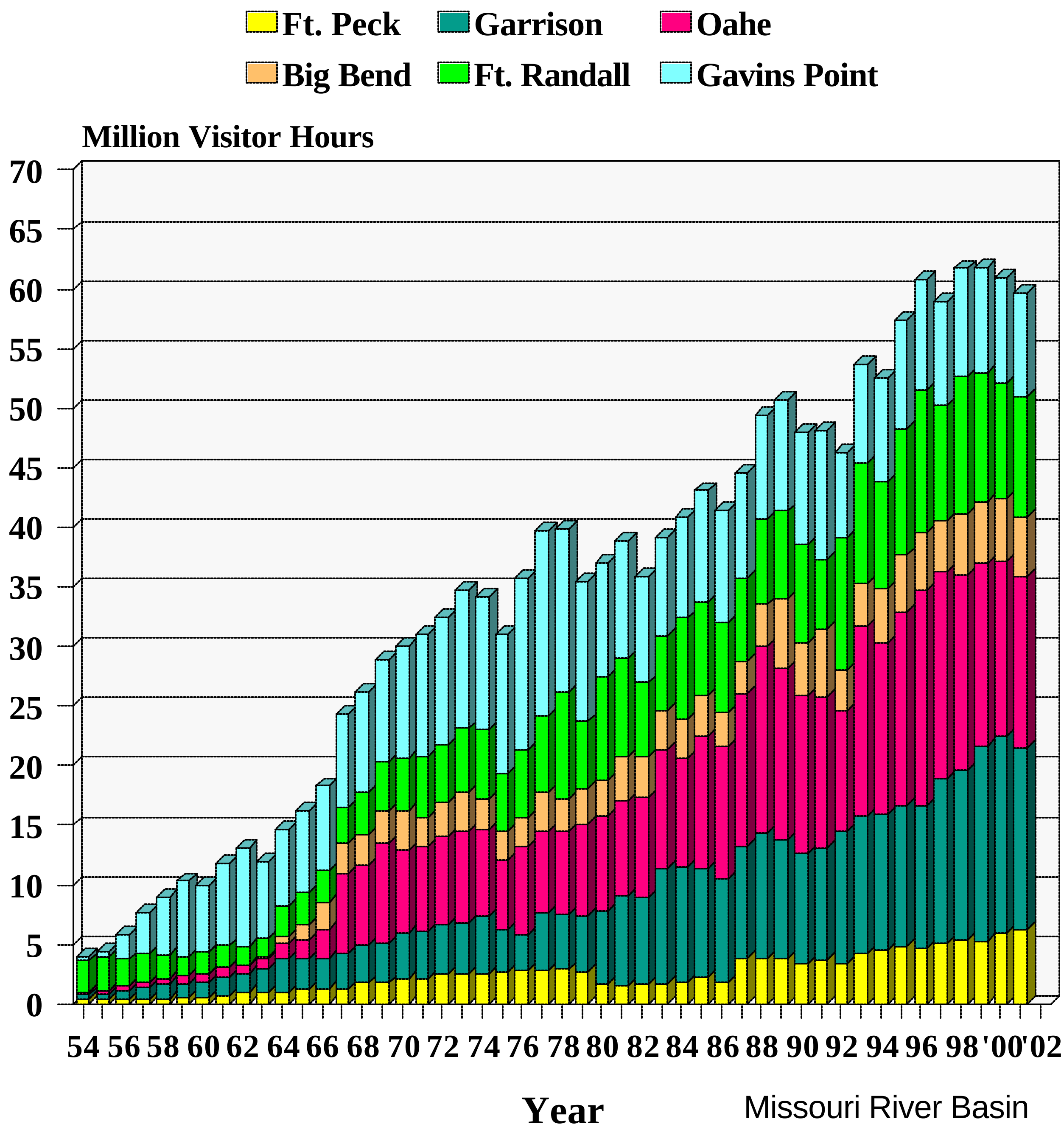
Missouri River Basin
Simulated Regulation For
1951-1952-1944-1945 Flood Combination
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
Plate A-1

Simulated Regulation For 1951-1952-1944-1945 Flood Combination - Sheet 2

		1952				1944								1945		
		22-Mar	31-Mar	30-Apr	31-May	30-Jun	31-Jul	31-Aug	30-Sep	31-Oct	15-Nov	30-Nov	31-Dec	31-Jan	28-Feb	15-Mar
Fort Peck																
Reach Inflow, 1000 AF	9036	283	363	1541	1693	1740	914	375	309	339	163	163	270	375	343	163
Evap, 1000 AF	518	0	0	0	34	25	101	107	99	66	29	29	24	0	0	0
Inflow Adjust, 1000 AF	-1251	2	3	-162	-523	-540	-304	-46	136	12	25	25	-5	38	67	18
Modified Inflow, 1000 AF	7266	285	366	1379	1135	1174	508	221	345	284	159	159	240	413	410	182
Storage, 1000 AF	15644	15846	16123	17205	18033	18909	18928	18298	17799	17313	17071	16828	16374	16018	15728	15539
Pool Elev, FT-MSL	2236.0	2236.9	2238.1	2242.8	2246.4	2250.0	2250.1	2247.5	2245.4	2243.3	2242.3	2241.2	2239.2	2237.7	2236.4	2235.5
Release, 1000 AF	7371	83	89	297	307	297	489	851	844	770	401	402	694	768	700	371
Release, 1000 CFS	10.2	6.0	5.0	5.0	5.0	5.0	8.0	13.9	14.2	12.5	13.5	13.5	11.3	12.5	12.5	12.5
Ave Power, MW	142	83	69	70	71	71	112	195	200	176	189	189	158	173	173	172
Peak Power, MW		200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
Energy, 1000 MWH	1251.3	14.0	15.1	50.8	52.8	51.2	83.8	145.3	144.0	131.2	68.3	68.2	117.6	129.4	117.4	62.1
Garrison																
Reach Inflow, 1000 AF	17222	129	166	4802	2097	4346	2469	567	395	460	214	214	250	238	365	508
Evap, 1000 AF	603	0	0	0	41	29	119	125	115	76	34	33	27	0	0	0
Inflow Adjust, 1000 AF	-929	57	73	131	-54	-749	-345	-64	-37	18	4	4	35	1	-6	0
Modified Inflow, 1000 AF	23060	270	329	5230	2309	3864	2494	1229	1087	1171	585	586	952	1007	1059	881
Storage, 1000 AF	18861	18962	18845	21969	22102	23664	23695	22898	22101	21315	20934	20555	20124	19440	18819	18808
Pool Elev, FT-MSL	1839.1	1839.4	1839.1	1848.1	1848.5	1852.7	1852.8	1850.7	1848.5	1846.3	1845.2	1844.2	1843.0	1840.9	1839.0	1838.9
Release, 1000 AF	23113	168	446	2106	2176	2302	2464	2025	1884	1958	965	965	1383	1690	1681	892
Release, 1000 CFS	31.9	12.2	25.0	35.4	35.4	38.7	40.1	32.9	31.7	31.8	32.5	32.5	22.5	27.5	30.0	30.0
Ave Power, MW	393	152	303	438	447	460	460	421	402	402	406	404	281	339	364	362
Peak Power, MW		454	452	460	460	460	460	460	460	460	460	460	460	460	452	452
Energy, 1000 MWH	3447.0	25.6	65.7	315.6	332.8	331.2	342.2	313.3	290.0	299.1	146.4	145.7	209.5	252.3	247.2	130.4
Oahe																
Reach Inflow, 1000 AF	6456	47	60	3650	230	1299	40	145	61	30	76	76	-105	16	365	463
Evap, 1000 AF	504	0	0	0	37	26	101	106	95	61	27	27	22	0	0	0
Inflow Adjust, 1000 AF	-529	-12	-16	-288	-18	-70	-34	-48	-18	-3	-2	-2	119	-2	-93	-41
Modified Inflow, 1000 AF	28535	203	490	5468	2351	3505	2369	2016	1831	1924	1012	1013	1374	1704	1953	1314
Storage, 1000 AF	20153	20007	20141	23506	23506	23506	23431	22010	20498	19827	19806	19762	18872	18989	19884	20797
Pool Elev, FT-MSL	1610.3	1609.9	1610.3	1620.0	1620.0	1620.0	1619.8	1615.9	1611.4	1609.3	1609.2	1609.1	1606.4	1606.7	1609.5	1612.3
Release, 1000 AF	27890	349	357	2103	2351	3505	2443	3437	3343	2596	1033	1057	2264	1588	1058	401
Release, 1000 CFS	38.5	25.1	20.0	35.4	38.2	58.9	39.7	55.9	56.2	42.2	34.7	35.6	36.8	25.8	18.9	13.5
Ave Power, MW	493	331	264	477	525	685	545	685	685	554	453	464	476	332	246	180
Peak Power, MW		685	685	685	685	685	685	685	685	685	685	685	685	685	685	685
Energy, 1000 MWH	4326.7	55.7	57.1	343.8	390.9	493.2	406.0	509.6	493.2	412.7	163.4	167.1	354.3	247.3	167.3	65.1
Big Bend																
Evap, 1000 AF	60	0	0	0	4	3	11	12	11	7	3	3	3	0	0	0
Ave Power, MW	168	112	86	139	144	219	159	257	258	202	169	174	180	123	86	60
Peak Power, MW		471	459	349	410	331	491	491	491	529	537	538	531	506	495	495
Energy, 1000 MWH	1480.8	18.9	18.7	100.5	107.2	157.9	118.8	191.2	186.0	150.8	61.1	62.7	134.2	92.2	58.6	21.8
Fort Randall																
Reach Inflow, 1000 AF	2598	112	144	1305	139	490	179	180	54	-8	25	25	-174	-69	55	140
Evap, 1000 AF	71	0	0	0	6	3	17	13	12	8	3	3	2	0	0	0
Inflow Adjust, 1000 AF	-187	-3	-4	-19	-28	-41	-35	-33	-18	1	-1	-1	1	1	-1	-6
Modified Inflow, 1000 AF	30169	458	497	3389	2452	3947	2559	3559	3355	2572	1049	1074	2085	1520	1112	535
Storage, 1000 AF	3701	3950	4072	5131	4549	5306	3746	3746	3746	3218	2868	2543	3184	3598	3701	3701
Pool Elev, FT-MSL	1353.0	1356.0	1357.4	1368.6	1362.6	1370.3	1353.6	1353.6	1353.6	1346.9	1342.2	1337.5	1346.5	1351.8	1353.0	1353.0
Release, 1000 AF	30168	208	375	2331	3034	3190	4118	3559	3355	3101	1399	1399	1444	1106	1008	535
Release, 1000 CFS	41.6	15.0	21.0	39.2	49.3	53.6	67.0	57.9	56.4	50.4	47.1	47.1	23.5	18.0	18.0	18.0
Ave Power, MW	277	126	177	340	360	360	360	336	336	322	299	277	173	143	147	148
Peak Power, MW		346	352	368	368	368	337	337	337	307	285	264	305	329	334	334
Energy, 1000 MWH	2430	21.2	38.4	245.3	267.8	259.2	267.8	250.4	242.3	240.0	107.7	100.0	129.0	107.1	100.3	53.5
Gavins Point																
Reach Inflow, 1000 AF	2060	212	273	271	155	218	137	103	79	101	53	53	87	113	133	71
Evap, 1000 AF	31	0	0	0	2	1	6	6	6	4	1	1	1	0	0	0
Inflow Adjust, 1000 AF	-152	-4	-5	-6	-9	-24	-32	-30	-22	-14	-2	-2	2	2	1	-4
Release, 1000 AF	32045	416	643	2596	3178	3382	4216	3625	3405	3183	1448	1448	1532	1221	1142	601
Release, 1000 CFS	44.2	30.0	36.0	43.6	51.7	56.9	68.6	59.0	57.2	51.8	48.7	48.7	24.9	19.9	20.4	20.2
Ave Power, MW	84	88	98	95	92	90	86	89	90	92	93	93	74	61	63	62
Peak Power, MW		99	98	95	92	90	86	89	90	92	93	93	99	82	84	83
Energy, 1000 MWH	738.5	14.8	21.2	68.8	68.9	65.3	64.3	66.9	65.2	68.8	33.7	33.7	55.8	45.8	42.7	22.5
Mainstem System																
Reach Inflow, 1000 AF	41390	914	1175	12600	4915	8162	4659	1800	1124	1067	571	571	326	679	1346	1481
Evap, 1000 AF	1790	0	0	0	125	90	356	370	340	224	100	99	81	0	0	0
Inflow Adjust, 1000 AF	-3291	36	46	-375	-652	-1430	-799	-268	-4	3	19	19	151	39	-38	-40
Storage, 1000 AF	60528	60934	61350	69979	70358	73553	71968	69121	66314	63841	62848	61856	60722	60213	60300	61013
Ave Power, MW	1559	894	1000	1562	1640	1886	1724	1984	1973	1750	1612	1604	1344	1174	1081	987
Peak Power, MW		2256	2247	2157	2215	2135	2259	2263	2263	2274	2260	2241	2280	2263	2252	2251
Energy, 1000 MWH	13674.3	150.3	216.1	1124.8	1220.5	1358.0	1283.0	1476.8	1420.7	1302.6	580.6	577.5	1000.4	874.1	733.6	355.4
Service Level, 1000 CFS		55.0	55.0	60.0	65.0	70.0	75.0	65.0	60.0	60.0	60.0	60.0				
Navigation Season Length		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Control Point		11	992	992	992	992	992	994	994	994	994	994	11	11	11	11
Sioux City																
Reach Inflow, 1000 AF	4016	129	166	1031	601	69	920	430	226	145	38	38	-2	6	85	132
Inflow Adjust, 1000 AF	-241	-3	-4	-31	-20	-6	-49	-47	-45	-11	-4	-4	-1	-1	-6	-7
Modified Inflow, 1000 AF	3775	126	162	1000	581	63	871	383	181	134	34	34	-3	5	79	125
Flow, 1000 AF	35821	542	805	3595	3758	3445	5087	4008	3586	3317	1482	1482	1529	1226	1221	727
Flow, 1000 CFS	49.4	39.1	45.1	60.4	61.1	57.9	82.7	65.2	60.3	54.0	49.8	49.8	24.9	20.0	21.8	24.4
Omaha																
Reach Inflow, 1000 AF	1520	48	61	109	128	512	140	147	73	-1	19	19	-26	17	148	125
Inflow Adjust, 1000 AF	-35	-1	-1	-4	-4	-8	-6	-2	0	0	0	0	0	0	0	-8
Modified Inflow, 1000 AF	1485	46	60	105	124	504	134	145	73	-1	19	19	-26	17	148	117
Flow, 1000 AF	37326	564	847	3655	3880	3959	5147	4206	3674	3335	1514	1501	1578	1258	1364	836
Flow, 1000 CFS	51.5	40.7	47.5	61.4	63.1	66.5	83.7	68.4	61.8	54.3	50.9	50.5	25.7	20.5	24.3	28.1
Nebraska City																
Reach Inflow, 1000 AF	5708	242	311	644	886	1377	508	307	187	148	92	92	126	251	337	200
Inflow Adjust, 1000 AF	-916	-69	-89	-131	-118	-69	-2	-110	-75	-59	-37	-37	-50	-100	23	7
Modified Inflow, 1000 AF	4792	172	222	513	768	1308	506	197	112	89	55	55	76	151	360	207
Flow, 1000 AF	42125	729	1063	4152	4648	5270	5628	4421	3791	3431	1573	1556	1679	1414	1722	1041
Flow, 1000 CFS	58.1	52.5	59.6	69.8	75.6	88.6	91.5	71.9	63.7	55.8	52.9	52.3	27.3	23.0	30.7	35.0
Kansas City																
Reach Inflow, 1000 AF	12903	437	563	914	1638	1117	1596	1755	1209	549	206	206	1197	433	542	539
Inflow Adjust, 1000 AF	-956	-9	-11	-36	-116	-402	-251	-131	0	0	0	0	0	0	0	0
Modified Inflow, 1000 AF	11946	428	551	878	1522	715	1345	1624	1209	549	206	206	1197	433	542	539
Flow, 1000 AF	54097	1124	1590	4969	6167	5998	6874	6115	5020	4005	1795	1762	2975	1867	2256	1571
Flow, 1000 CFS	74.7	81.0	89.1	83.5	100.3	100.8	111.8	99.5	84.4	65.1	60.4	59.3	48.4	30.4	40.3	52.8
Boonville																
Reach Inflow, 1000 AF	5717	545	701	544	1382	-36	26	383	339	255	67	67	587	32	408	415
Inflow Adjust, 1000 AF	-107	-5	-6	-18	-18	66	4	-38	-34	-26	-5	-5	0	0	-13	-7
Modified Inflow, 1000 AF	5610	540	695	526	1364	30	30	345	305	229	62	62	587	32	395	407
Flow, 1000 AF	59733	1632	2262	5434	7528	6041	6804	6530	5345	4259	1874	1824	3662	1918	2644	1968
Flow, 1000 CFS	82.5	117.6	126.7	91.3	122.4	101.5	110.7	106.2	89.8	69.3	63.0	61.3	59.6	31.2	47.2	66.2
Hermann																
Reach Inflow, 1000 AF	11392	621	799	1729	1156	436	489	995	1036	893	142	142	687	400	737	1129
Inflow Adjust, 1000 AF	-28	-21	-27	-82	-83	64	100	122	205	-112	-30	-30	-27	-26	-45	-33
Modified Inflow, 1000 AF	11364	600	771	1647	1073	500	589	1117	1241	781	111	111	660	374	692	1095
Flow, 1000 AF	71110	2216	3021	7050	8600	6548	7344	7682	6595	5053	1994	1936	4372	2302	3332	3058
Flow, 1000 CFS	98.2	159.6	169.3	118.5	139.9	110.0	119.4	124.9	110.8	82.2	67.0	65.1	71.1	37.4	59.5	102.8

Missouri River Basin
Simulated Regulation For
1951-1952-1944-1945 Flood Combination
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
Plate A-2

Missouri River Main Stem
Project Visits
1954 to 2002



Missouri River Basin
Mainstem Project Visits
U.S. ARMY ENGINEER DIVISION, NORTHWESTERN
CORPS OF ENGINEERS, OMAHA, NEBRASKA
NOVEMBER 2003

Plate B-1